KNITTING CALCULATIONS

By

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KNITTING CALCULATIONS

(1) Many of us remember the introduction of weather calculations. Before that we guessed at the weather, were satisfied with our guessing, and scoffed at the very idea of calculating about it. How could one calculate about anything depending on so many indeterminate circumstances? Consequently, when weather forecasts were based on calculations, instead of guesses, we received them with due incredulity. We expected each one to go wrong, and those which did go wrong were promptly pointed to as evidence of the absurdity of attempting to calculate about something not susceptible of calculation. The forecaster and his forecasts were an inexhaustible source of jokes. But the conditions are different now. Altho there are still some who joke about the weather forecasts, the public as a whole has learned to respect the calculated forecasts and to scorn the mere guesses. The daily paper which does not print the forecasts where they may readily be found is not considered much of a paper; for everybody wants to know what the weather is going to be. The mariner, the farmer, the traveler, the business man, even the lady who has calls to make or the child who wants to give a party consults the calculated forecast.

Many lessons may be drawn from this bit of history. We may learn that a subject involving numerous apparently indeterminate factors may be susceptible of calculation, provided the calculations are based on the most determinate factors and proper allowance is made for the other factors. We may learn that an innovation which appears crude at first may develop a surprising degree of reliability. We may learn that the benefit to be gained by the substitution of calculation for guessing can not be judged adequately until we make use of the calculations.

Let us endeavor to bear these lessons in mind in our consideration of knitting calculations. First, since the factors involved in knitting are more determinate than those involved in the weather, knitting calculations are bound to come into use. Therefore, the proper attitude is not to oppose them or to ridicule them more than they deserve, but to accept them for what they are worth. What are they really worth?

(2) The Worth of Knitting Calculations

To attempt to say what knitting calculations are really worth is to attempt to prophesy; for that worth depends on general use of the calculations, and general use depends on the availability of much more data than we have at hand. For instance, the diameter of knitting yarn, one of the most necessary factors, is available to only a slight extent, and even then, not with a considerable degree of reliability. So, instead of endeavoring to tell the worth of knitting calcutions, we may better discuss the dependability of such calculations as may be made with the data at hand. This is no excuse for dropping the subject altogether; for complete data will not be collected until there is a demand for it, and the demand will not be made until the insufficiency of the present data is realized thru actual use of it. If automobilist had not used the poor roads they would not have agitated for good ones. Here follows a comparison of the calculated and actual results in a test case. A little piece of yarn was given to a calculator,

who measured it by coiling it, and made his calculations. Some cones of the yarn were given to a practical knitter to be made into fabric. After the calculations were made, the yarn was reeled to determine its number and the fabric was measured and weighed. All the calculated results are given and they are compared with what actual measurements were made.

(3) Comparison of Calculated and Actual Results

	Calculated	Actual	Difference	%
1/2 Coils	38.5			
Yarn	13.2	14.	- .8	- 5.7
Cut	9.	10.	-1.	-10.
Stitches	36.			
Wales	19.25	18.	+1.25	+ 6.95
Courses	24.	29.	-5.	-17.2
Pounds per square yard	.494	.476	+ .018	+ 3.78
Pounds per feed, 10 hours	9.74			
Square yards per feed, 10 hours	19.75			
Tensile strength lengthwise (of 1 inch strip)	78.			
Tensile strength crosswise	24.35			
Width, 600 needles	17.6	18.	- .4	- 2.2

The calculated results are surprisingly close to the actual results. If the courses show a 17% variation from the calculated results and the cut a 10% variation, this is not much against the calculations, for the knitter was free to select both the cut and the stitch. The other variations, 6% for yarn, 7% for wales, 4% for weight of fabric and 2% for width, show reliability of calculation comparable to that of industries which have attained a high degree of technical development; and ought to be sufficient to carry conviction of the dependability of knitting calculations.

(4) The Relations Which Underlie the Calculations

It may be seen by inspection of a piece of knitting that the width of the wale depends to a considerable extent on the thickness of the yarn; that four thicknesses lying side by side make up the width of the wale. Experimental investigation has shown that the length of yarn in the loop - which length decides the number of stitches per foot of yarn and the number of courses per inch - also depends, altho less definitely, on the thickness of the yarn. These relation afford a good basis for calculations concerning the dimensions of the fabric. then, it is evident that there must be some relation between the thickness of the yarn and the spacing of the needles on which the yarn is used. Two folds of an inch rope could not be crowded between needles only a quarter of an inch apart, and thread would not fill them sufficiently to be usable. Such a range of yarn thickness is evidently out of the question. Careful investigation shows that the general range is much more restricted than the range imagined even by knitters. The knitter who brags that he can use on his machine yarn twice as heavy as he is accustomed to using would generally be sadly embarrassed if you required him to

make good his boast, and remained to watch the operation of the machine. This relation of the yarn to the needles affords a very satisfactory basis for the calculation of knit-fabric production. All these relations and others are discussed in "The Science of "Knitting."

(5). The Influence of the Yarn Diameter

But to what extent can we depend of the thickness of the yarn? Let us consider the conditions involved. A yarn, nominally round, is run into a knitting machine under a certain feed tension, is formed into loops, and is drawn off under a certain take-up tension. Evidently, it is stretched, compressed, and distorted to an extent all through the operation. Whereas the cross section was originally circular or approximately so, the cross section in the fabric may diverge much from the circular form, and may be different in different places in the fabric. Let us grant all that. Then let us take a yarn one-fifth larger in diameter, and put it through the same operations on the same number of needles on a correspondingly coarser gage. There is every reason to believe that the fabric would be one-fifth wider. Indeed, extensive experimentation shows that when the conditions are made as nearly alike as is possible in two cases the widths of the fabric are very nearly proportional to the original diameters of the yarn. However, we know that we cannot exactly duplicate the conditions, so we are warranted in expecting that the widths would be exactly proportional to the yarn diameters if we could exactly duplicate the conditions. Therefore, if we base our calculations on the diameter of the yarn, and estimate on the other conditions we will have a fairly reliable basis. Moreover, as we progress with our calculations we may be able to reduce some of the other conditions to a calculation basis, also. For instance, the type of machine seems to have an influence on the width of the fabric: certain body rib machines make it slightly wider than the calculations call for, and certain ribbers (cuff machines, so called) make the fabric slightly narrower. The tendency of any machine may be determined by observation of the constant difference between the calculated width and the actual width when other conditions than the yarn diameter are not changed. Indeed, every knitter should observe and record the direction and extent of such tendencies, for the trade has need of that information.

(6) Diameter, Diameters, and Coils

Evidently it is necessary to know the thickness of yarn. This thickness is generally designated as diameter; but since the diameter is too small for convenient use, and since the number of diameters per inch corresponds better with the units used in the knitting, the latter or a reduction thereof, (as the diameters per half-inch) is preferable. As an illustration of the simplicity afforded by the use of diameters per inch, they vary in direct proportion with the wales, courses, stitches per foot of yarn, and cut of machine - four important factors involved; whereas the diameter of the yarn varies inversely. That is, when those factors increase, the diameter decreases, a relation much less comprehensible and convenient than the direction proportion. However, in the use of diameters per inch we encounter a language difficulty: diameters-per-inch is too cumbersome to say or write, and diameters is too readily confused with diameter. The author has adopted the term Coils instead of diameters, not only for its distinctiveness and shortness, but because it convorms to his methof of determining yarn size by

coiling the yarn on a watch-chain bar. For ordinary calculations the diameters per half-inch are the most satisfactory, and they are here designated Coils per Half-Inch, or $\frac{1}{2}$ Coils.

(7) How to Get the Coils Per Half-inch

The Coils per Half-Inch are simply the diameters per half-inch; that is, the number of threads, which, lying alongside as closely as they do in the fabric, will cover half an inch. Therefore, there is nothing mysterious or new about them. They may be found by measurement; may be derived by dividing by two the diameters tabulated in various textile books; or may be calculated from the yarn number in the manner shown later. The best procedure is to memorize them.

(8) Table of Diameters Per Half-inch (Here Called $\frac{1}{2}$ Coils) of Single, Mule-Spun, Carded, Cotton Yarn

Yarn Number	$\frac{1}{2}$ Coils	Yarn Number	$\frac{1}{2}$ Coils
4	21	24	51.5
6	26	26	53
8	30	28	55.5
10	33	30	57.5
12	36	32	59
14	39	34	61
16	42	36	63
18	44.5	38	65
20	47	40	66
22	49		

(9) The Coils Should be Memorized

This is not a difficult table to learn, even in its entirety. However, most of those concerned with knitting calculations would use only a portion of the table. The pros and cons of memorizing this table are simple. With the coils the usual knitting problems may be solved mentally, or nearly so: with the yarn number, square-roots must be used. The time required to memorize the table would be spent in solving only a few problems by means of the yarn number; so it is far more efficient and satisfactory to memorize the table. The reader is not restricted to this table. The yarn he uses may be larger or smaller; in which case each number of coils is decreased or increased by a certain proportion. Let him tabulate the yarn numbers and whatever coils he may wish; hang the tabulation up where he can see it frequently; and, whenever the yarn number comes to mind, think of the corresponding number of coils. He will soon come to think of the yarn in terms of its coils, and thereafter he will be able to solve many of his problems mentally or nearly so.

(10) Materials

Altho the principles involved in these calculations apply to any material, cotton is the material generally considered, because cotton is most used in practice, because the diameter of cotton yarn has been determined more extensively

than the diameter of other yarn, because cotton yarn is readily susceptible of measurement, and because the cotton count is probably used more extensively than any other yarn count.

(11) Materials Other than Cotton

For materials other than cotton, allowance must be made for difference in the size of the yarn - between cotton and that material - when there is a difference. For instance when woolen yarn is considered, and the cotton equivalent is used, if the woolen yarn is thicker, the courses, wales, thicknesses and stitches per foot will be less than the formulas give. When the yarn diameters for these other materials are determined, the constants in the formulas may be modified accordingly. The general production formulas, the general knit fabric formula, and those formulas which do not depend on the diameter of the yarn, hold good for any material when the yarn number is transformed to the cotton count.

(12) Regular Fabrics

We increase our understanding of things, and our ability to communicate that understanding, by classifying them. Knit fabric is classified according to the form of the stitch into flat fabric, ribbed, warp, etc.; but it is only very recently that we have come to a classification according to the size of the loop measured by the diameter of the yarn of which it is formed. The basis of this classification is correspondence of characteristics, no matter what the size of the yarn; that is, the relation of the strength in each direction, the elasticity in each direction, and the number of stitches in each direction is the same. Experience shows that fabric with 25% more courses than wales represents what is generally considered to be good knitting; so the relation of the length of the loop to the diameter of the yarn in that fabric has been found, and all fabrics having that relation have been called regular, to distinguish them from fabrics having more or less yarn in the loop. Complete sets of formulas have been derived for these regular fabrics for use when we have no other standard of reference. For instance, suppose we are asked what is the weight per square yard of rib fabric made of number 16 yarn. The formula for that weight is (13) $1.808 \div \sqrt{\text{Yarn number}} = 1.808 \div \sqrt{16} = 1.808 \div 4 = .45$. That is, one square yarn of rib fabric such as is generally made of number 16 yarn weighs .45 of a pound. However, when we have a weight to figure from, we may use other rules, which are also given. The adoption of regular fabrics for a standard is not in the least an attempt to exclude different fabrics from consideration, but to establish a basis for understanding in case we have no other basis.

(14) Strength of Fabric

The strength calculations are based on the average of the best obtainable tests of soft-twist American yarn. For

(15) $\text{yarn diameter} = \dfrac{1}{21\sqrt{\text{Number}}}$ that average is

(16) $600 \times (\text{yarn diameter})^2$. The units are pounds and inches. Those who use yarn of different strength may modify the formulas accordingly.

(17) The Simplicity and Unity of Knitting Calculations

Knit fabric, as compared with woven fabric, has two characteristics of much importance in connection with calculations. One of these characteristics is that the yarn is, almost without exception, of the same size and character throughout. The other characteristic is that, owing to the formation of the loop, the wales tend to come close together, so that the width of the fabric - for a given number of needles - is determined very largely by the diameter of the yarn. Woven fabric is generally made with yarns different is size and characteristics and the threads per inch, below a certain maximum, are not necessarily determined by the size of the yarn. Consequently, the calculations applicable to knit fabrics have a simplicity and a unity far exceeding those of woven fabrics.

(18) Choice of Units

Unfortunately that simplicity of principle is clouded by inadequacy of the available units. The yarn number is generally usable only as a square or as a square-root; the tabulated diameters of yarns are very incomplete, and are theoretical diameters instead of those which affect the machine and the fabric; and convenient methods of determining the diameter are little understood and less practiced. Naturally there will be much opportunity for choice in the selection of the unit for any particular case, for there is the double consideration of suitability for the calculation and availability of the unit. Also, the close connection of knitting calculations makes possible many transformations from one quantity to another: the stitches may be determined from the cut of the machine; the longitudinal strength may be determined from the wales per inch; etc. The advantage afforded by the very number of these calculations is offset by the aversion of the beginner to take up what seems to be a stupendous task. It is necessary therefore to impress on him that each calculation may be used without learning any other, and that a complete set of calculations is available with any one unit. It is not necessary to take the whole dose in order to get the benefit. Indeed, he may with a very few calculations solve all the problems which generally come to him. If he desires to go more deeply into the subject he may do so, but it is not necessary.

Probably the best way to dispel the apparent confusion is to explain in the first place the connection of the customary units, so that the user may derive one from any other, according to his choice.

The yarn number is the most available unit. A series of measurements of mule-spun carded cotton yarn showed that the average diameter was given by the equation

(19) Yarn diameter $= 1 \div 21 \sqrt{\text{Yarn number}}$, according to which

(20) Yarn diameters per inch $= 21 \sqrt{\text{Yarn number}}$.

If yarn of different diameter is used the constant, 21, may be changed accordingly.

There is a convenient means of determining the diameter of the yarn by coiling

it on a wire or on a watch-chain bar and making a simple calculation. For the yarns ordinarily used, the number of coils per half-inch may be determined without the calculation, and are much more satisfactory, because many of the demensions of the fabric are directly proportional to them and because they are integral instead of fractional. Those who do not make the actual determination may derive them from the yarn number by the expression

(21) $\frac{1}{2}$ Coils = 10.5 $\sqrt{\text{Yarn number}}$. Evidently,

(22) Yarn diameter = 1 ÷ 2 x $\frac{1}{2}$ Coils.

The following table of numbers and their square roots obviates the necessity of calculating the square roots of the yarn numbers.

(23)

Number	Square Root	Number	Square Root
5	2.236	20	4.472
6	2.450	21	4.583
7	2.646	22	4.690
8	2.828	23	4.796
9	3.	24	4.899
10	3.162	25	5.
11	3.317	26	5.099
12	3.464	27	5.196
13	3.606	28	5.292
14	3.742	29	5.385
15	3.873	30	5.477
16	4.	31	5.568
17	4.123	32	5.657
18	4.243	33	5.745
19	4.359	34	5.831

(24) Speed of Machines

It is customary to run the machines at a fixed needle speed, as high as the work will stand without excessive damage and waste. Accordingly, small cylinders run fast and large cylinders run slow, compared with the average size. Generally a certain number of revolutions is adopted for the average size, say a 20-inch cylinder, which size is convenient as a basis of comparison. (25) The diameter multiplied by the revolutions is called the diametral revolutions, and this number is used to determine the revolutions of the other sizes.

Latch-needle rib machines are supposed to run on cotton work at about 35 revolutions for a 20-inch cylinder. Then the diametral revolutions are 20 x 35 = 700. (26) To find the number of revolutions for any other size, divide 700 by that size. For instance, the number of revolutions for a 16-inch cylinder is 700 ÷ 16 = 44.

Loop-wheel spring-needle machines are supposed to run at about 50 revolutions

for a 20-inch cylinder; so the diametral revolutions are 1,000; (27) and revolutions = 1,000 ÷ diameter of cylinder. A 24-inch cylinder should run at 1,000 ÷ 24 = 42.

The above mentioned speed standards are used in the calculations unless other standards are mentioned. However, anyone may use his own standard, according to the exigencies of his work.

(28) Yarn Counts

There are two yarn numbering systems in general use; namely, (1), the length of a standard weight, and, (2), the weight of a standare length.

In the first system, the length is expressed in hanks. For instance, number 20 cotton is called number 20 because a length of 20 hanks weighs a pound, the standard weight. (29) To find the length in yards in one pound, the number of hanks in a pound must be multiplied by the length in yards of one hank. In this case, the length in yards in a pound is 20 multiplied by 840, which is 16,800.

In the second system, the weight is generally expressed in grains, and the standard length is generally expressed in yards. For instance, the Cohoes standard is the weight in grains of 6 $\frac{1}{4}$ yards.

The system of numbering yarn by the diameters (coils) per inch has been adopted to a considerable extent in weaving calculations. It is preeminently useful in knitting calculations, so it is used extensively in this series. However, this topic has to do with the older system only, not the diameters (or coils).

(30) Length-of-a-Standard-Weight System

Prominent Counts

Name	Cut (Lea)	Run.	Cotton.	Worsted.	Metric.
Yards in one-pound hank	300	1600	840	560	496 (1000 meters per kilogram)
Proportional numbers	112	21	40	60	67.74

Transformations within the system may be effected by means of the yards in a hank, but more readily by means of the proportional numbers. It is evident, that of two counts the one with the longer hank has the lower number. The cotton number is lower than the worsted number. (31) To transform cotton count to worsted count we have the proportional numbers 40 and 60, and since we are to get a higher number, 60/40 or 3/2 is the quantity by which we are to multiply the cotton number to get the worsted number. Number 20 cotton multiplied by 60/40 or 3/2 equals 30, the worsted number. Transformations between any two counts in the above table are made in the same manner.

(32) Weight-of-a-Standard-Length System

Name.	Cohoes.	Amsterdam.	Canadian.	New Hampshire.	Silk	Denier
	Counts in Use					
Standard length	$6\frac{1}{4}$	$12\frac{1}{2}$	20	50	36.57	633.9
Proportional numbers	25	50	80	200	146.28	2535.6

The proportional numbers facilitate transformation. Of any two counts in this system the one with the greater length has the higher number, and this is a guide to the use of the proportional numbers. For instance, to transform number 10 in the Amsterdam standard to the Canadian standard we have two proportional numbers, namely, 50 and 80. (33) Since the Canadian number will be higher than the Amsterdam number, we should multiply the latter by 80/50 or 8/5. 10 x 8/5 = 80/5 = 16, the grains, Canadian, of 10 grain, Amsterdam yarn.

(36) Constants for Transformation Between the Two Yarn-Numbering Systems

	Cut(Lea).	Run.	Cotton.	Worsted.	Metric
Cohoes	145.82	27.34	52.08	78.12	88.20
Amsterdam	291.70	54.68	104.16	156.25	176.40
Canadian	466.70	87.50	166.70	250.	282.25
New Hampshire	1166.80	218.72	416.64	625.	705.60
Silk	853.33	159.37	304.76	457.14	516.31
Denier	1489.	2782.	5315.	7972.	

The second yarn numbering system, the weight-of-a-standard-length, makes the number increase as the weight of the yarn increases, and this is a desirable characteristic; but the counts in this system are not in general use, so they are not introduced in the calculations. It frequently happens, however, as in a knitting mills where woolen yarn is spun on mules, that all the yarn in the mill is numbered in some count of the weight-of-a-standard-length system; so some of the calculations are made more readily by using the count in which the yarn comes. (37) For two-thread work the sum of the numbers is the equivalent number, and (38) the proportion of either thread in the fabric (when the stitches are the same) is the number of that thread divided by the sum of the numbers of the two threads. However, for general fabric calculations, it will be found advisable to use the solutions given, as they have been selected for their simplicity.

(39) Single Equivalent of Two Yarns

The single equivalent of two yarns is their product divided by their sum.

(40) Example. What is the single equivalent of a number 10 yarn and a number 20 yarn?

The product of 10 and 20 is 200; the sum of 10 and 20 is 30; and 200 divided by 30 equals 6.7, the number of the single equivalent.

(41) Example. A manufacturer is making 22-gage spring-needle fleeces and is using a number 26 face thread and number 26 binder. He hears that a competitor is using for the same gage a number 22 face thread and a number 30 binder. What are the single equivalents in each case.

(42) (1) $\frac{26 \times 26}{26 + 26} = \frac{686}{52} = 13$

(43) (2) $\frac{22 \times 30}{22 + 30} = \frac{660}{52} = 12.7$

The second combination is slightly heavier than the first.

Notice that when the two yarns are alike the single equivalent is half the number; that is, two number 26 yarns are equivalent to one number 13.

(44) Example. A machine is run with 18 cotton and 24 worsted. What is the single equivalent?

Number 24 worsted is equivalent to number 16 cotton.

(45) $\frac{18 \times 16}{18 + 16} = \frac{288}{34} =$ 8.5, the single equivalent.

(46) Single Equivalent of Three or More Yarns

The simplest method of obtaining the single equivalent of three or more yarns is to find the equivalent of one pair, then combine that with the next yarn, and so on until all the yarns are combined. There are expressions for the combination of any number of yarns; but they are not readily remembered, and are not generally at hand when needed. The expression for combining two yarns is so simple that it is readily remembered; and since it may be used successively to combine any number of yarns, it is preferable to depend on it for all such combinations rather than to risk mistakes by endeavoring to keep in mind each different expression.

(47) Example. What is the equivalent of 12, 18, and 36 yarn?

Combine the 12 and 18 yarn.

(48) $\frac{12 \times 18}{12 + 18} = \frac{216}{30} = 7.2$

Now combine the 6.2 yarn with the 36.

(49) $\frac{7.2 \times 36}{7.2 + 36} = \frac{259.2}{43.2} =$ 6, the single equivalent of 12, 18 and 36 yarn.

(50) One of Two Yarns Equivalent to a Third Yarn

To find one of two yarns equivalent to a third yarn, divide the product of

the given yarn and the equivalent by their difference.

(51) Example. What number yarn must be combined with number 10 to make the equivalent of number 6?

$$\frac{10 \times 6}{10 - 6} = \frac{60}{4} = 15$$

(52) Example. Prove the above example.

The number 10 and the number 15 combined should be equivalent to the number 6.

$$\frac{10 \times 15}{10 + 15} = \frac{150}{25} = 6$$

(53) Proportions of Yarn in Two-Thread Work - Equal Stitches

The frequency with which two-thread work is knit makes it desirable to be able to calculate the proportions of the threads in the fabric. The simplest case is that in which the two yarns are knit with the same stitch, which is generally the case when both yarns are drawn into the machine with the same feeding device, as with a latch needle or with a single loop-wheel. The case is not so simple when a separate feeding device is used with a separate stitch for each thread, as in the knitting of flat fleeces, or two-thread work with two sinkers at a feed.

When the stitches for each yarn are alike the yarn numbers are the only factors involved. They should be expressed in the same yarn count, preferably the cotton count, altho one of them will probably be worsted or possibly silk.

(54) The proportion of one yarn in the fabric is the number of the other yarn divided by the sum of the numbers of the two yarns.

(55) Example. A two-thread fabric is knit of number 16 and number 24 yarn. What is the proportion of each in the fabric.

To find the proportion of number 24 yarn divide the number of the other yarn, namely, 16, by the sum of the numbers of the two yarns, which sum is 40. $16 \div 40 = .40$. Then the proportion of 16 yarn would be .60; but solve for the proportion of 16 yarn in order to prove the work. $24 \div (16 + 24) = 24 \div 40 = .60$. Since the yarn number is an inverse measure of the weight of the yarn, it is evident from inspection in this case that there will be half as much more of one yarn than the other and that there will be the greater weight of the lower number.

(56) Proportions of Yarn in Two-Thread Work - Unequal Stitches

When the stitches are equal the proportion of either thread in the fabric is the number of the other thread divided by the sum of the numbers of the two threads.

Consider two yarns of the same size but knit with unequal stitches as in the

case of plated work, in which the face thread is preferably knit with less stitches per foot of yarn in order to make the face loop longer than the loop on the back. Since an increase in the stitches per foot of yarn causes a decrease in the amount of yarn used, the proportion of either yarn in the fabric would be the stitches per foot of the other yarn divided by the sum of the stitches of the two yarns. In other words, the stitches have the same inverse effect on the proportions that the yarn does.

Consequently, (57) for two-thread work in which both the yarns and the stitches are different, the proportion of either yarn in the fabric is the product of the other yarn and stitches divided by the sum of the products of each yarn and its stitches. That is, multiply together each yarn and its stitches, and divide one product by the sum of the two products: the quotient is the proportion of the other yarn.

(58) Example. A 9-pound (to the dozen of men's garments), 20 gage, plated fabric is made of number 30 worsted at 57 stitches per foot of yarn and number 14 cotton at 63 stitches. What is the proportion of wool and cotton in the fabric?

Reduce the worsted number to the cotton number.

	(Worsted number)	(Reduction factor)		(Cotton number)
(59)	30	x 2/3	=	20

Thread	Number	Stitches per foot	Products of stitches and numbers	Opposite Products	Total	Proportions (Opposite products divided by total)
Back	14	63	882	1140	2022	.564
Face	20	57	1140	882		.436
		Total	2022			1.000

The fabric is 44% wool and 56% cotton.

(60) Gage and Cut

The gage and the cut are each the number of needles per unit of length.

(61) Cut is the number of needles per inch of needle line. It is applied generally to needle beds which are milled or cut, such as those of latch-needle machines. When interlocking sets of needles are used, as in rib machinery, the cut on only one needle bed - generally the cylinder - is considered.

(62) The old original knitting gage is the number of needles per inch-and-one-half. It was expressed as the number of two-needle leads in three inches, because the needles were leaded in pairs; but that is the same as the number of needles per inch-and-one-half.

There are hybrid gages, such as the number of needles per two-inches; but

these are as undesirable as the original gage, and lack even the justification of well-established use. In the interest of simplicity it seems desirable that needles-per-inch, even when the number is fractional, be used to displace gage as a standard for the needle spacing of machines.

Gage is also used to indicate the thickness of latch needles. Whatever significance it may have had as a standard has been lost, and is now principally a source of confusion and vexation. The tendency is to substitute the word "thickness" for it, and to express the thickness in thousandths of an inch.

The original knitting gage has deteriorated in its application to circular machines through measurement outside of the needle line, or on the chord, or other defective measurement. Similar errors have crept into standard cuts, also. In these calculations such errors will be neglected. Whoever desires to reckon with them may obtain the exact number of needles per inch from the maker of the machines in question.

(63) Example. A spring-needle machine is 14 gage. What cut is it?

Cut is the needles per inch, and gage is the number of needles per inch-and-one-half. Therefore the cut of the spring-needle machine is,

$$14 \div 1.5 = 9.33$$

(64) Example. A visitor to a latch-needle mill asks the knitter what the gage of the machines is. They are 8-cut. How shall the knitter answer intelligently?

Since machine gage is the number of needles in an inch-and-a-half, and cut is the number of needles in an inch, it is merely necessary to tell the number of needles in an-inch-and-a-half, which is of course 1/2 more than 8, namely 12.

(65) Example. A machine is 20 inches in diameter and contains 500 needles. What is the cut?

The length of the needle line is $20 \times \frac{22}{7} = \frac{20 \times 22}{7}$ and

500 divided by the length of the needle line is

$$\frac{500 \times 7}{20 \times 22} = 8\text{, nearly.}$$

(66) Example. A spring-needle, loop-wheel machine 20 inches in diameter contains 988 needles. What is the gage?

Solve for the cut, and then increase the cut by 50% to get the gage. The length of the needle line is $20 \times \frac{22}{7}$ and 988 divided by the length of the needle line is $\frac{988 \times 7}{20 \times 22} = 15.72$. The machine is nominally 24 gage. The difference between the actual and nominal gages gives a fair idea of the discrepancy frequently found in practice.

(67) Yarn and Cut of Machine

Probably the best conception of the relation of the yarn to the cut of the machine is obtained by imagining pieces of the yarn laid alongside, and a needle laid on every 5th, 6th or 7th needle, according to the type of machine in question. For a straight, jack-sinker,spring-needle machine the needles would be spaced 4 1/5 threads; for a latch-needle hosiery machine or a spring-needle loop-wheel machine about 5 threads; for a circular spring-needle rib machine about 6 2/3 threads; for a latch-needle rib machine about 8 1/2 threads. Then, whatever the size of the thread, the needle spacing would correspond, for the distance between the needles would be proportional to the size of the yarn. We could take the diameter of the yarn and multiply it by 4 1/5, 5, 6 2/3, 8 1/2 - according to the type of machine under consideration, and obtain the needle spacing. But, instead of using the needle spacing in practice, we use the number of needles in a certain space - an inch, or an inch-and-a-half - and that number decreases as the diameter of the yarn increases, so the diameter would have to be used as an inverse proportion. To obtain a direct proportion the diameters per inch, or preferably the coils per half-inch, may be used,for both they and the cut increase, or decrease, together. The coils per half-inch would be divided by half of the above numbers to obtain the cut. If the reader uses a machine not in the above list, or if he prefers a different proportion than the one given for any machine in the list, he has merely to divide the coils per half-inch by half the cut in order to get the number, which should hold for all other cuts of that type of machine. For instance, suppose he uses number 8 yarn on a 10-cut latch-needle machine for making flat work. Approximately 60 diameters of the yarn make up one inch; and ten of the needles occupy an inch; so there are 6 diameters of yarn to one needle. Consequently, if we divide the diameters per inch by 6, or the diameters (coils) per half-inch by 3, we get the cut.

Coarse machines, say 5-cut latch-needle rib, and 10-gage loop-wheel machines and coarser, will not take as heavy yarn as average-gage machines, because they are not as well designed as the average-gage machines. Special constants may be used for these coarse machines.

(68) Example. A yarn coils 43 turns per half-inch(about number 17). What is a suitable cut for rib work?

(69) Cut = 1/2 Coils ÷ 4.3, = 43 ÷ 4.3 = 10.

(70) Example. The diameter of a yarn is .01 (about number 23). What is a suitable cut for latch-needle, rib work?

(71) Cut = 1 ÷ Diameter x 8.6
= 1 ÷ .01 x 8.6
= 1 ÷ .086
= 11.6 say 12 cut.

(72) Example. A latch-needle rib machine with external dial runs satisfactorily on 11 cut with two-thread combinations equivalent respectively to 8.5 and 6.86. What is the Yarn-Cut formula for this machine.

(73) Yarn = $\frac{(\text{Cut})^2}{\text{Constant.}}$ (74) Constant = $\frac{(\text{Cut})^2}{\text{Yarn}}$ -

(75) $\begin{cases} (1) & 121 \div 8.5 = 14.3 \\ (2) & 121 \div 6.86 = 17.7 \end{cases}$

The total of 14.3 and 17.7 is 32; the average is 16; so the Yarn-Cut formula for this type of machine for a two-thread equivalent is

(76) Yarn = $\frac{(\text{Cut})^2}{16}$

Fortunately the yarn number may be determined from the cut without much trouble; and this is one of the frequent applications of the ralation.

(77) Example. A mill is equipped with 8-cut rib machines of the usual type. What is a good yarn to use?

(78) Yarn = Cut x Cut ÷ 6
= 8 x 8 ÷ 6
= 64 ÷ 6
= 10.7, say 11

(79) Example. A straight, jack-sinker, spring-needle machine, 25 gage, runs satisfactorily on woolen yarn equivalent to 11.4 cotton number. What is the yarn formula for this machine for corresponding running conditions?

(80) Yarn = Cut x Cut ÷ A constant. Therefore,

(81) The constant = Cut x Cut ÷ Yarn
= 25 x 25 ÷ 11.4
= 625 ÷ 11.4
= 55.

The yarn rule for this machine is

(82) Yarn = Cut x Cut ÷ 55

(83) Example. A mill is running number 16 yarn (42 coils to the half-inch) on 24 gage loop-wheel machines. It is contemplated to add both latch-needle and spring-needle rib machines. What would be appropriate cuts for the same yarn?

Latch. (84) Cut = $\frac{1}{2}$ Coils ÷ 4.29 =

(85) 42 ÷ 4.29 = 10

Spring-needle. (86) Cut = $\frac{1}{2}$ Coils ÷ 3.32 =

(87) 42 ÷ 3.32 = 12.7

(88) Wales

(89) Example. A yarn is .01 inch in diameter (about number 23). What will be the width of the wale made of it?

The width of the wale is made up of four thicknesses of yarn, therefore,

$.01 \times 4 =$ Width of wale $= .04$

(90) Example. A yarn is .015 inch diameter (about number 10). How many wales per inch will there be in the fabric made of it?

The width of the wale will be (91) $.015 \times 4 = .06$, and the number of wales per inch will be $1 \div .06 = 16.7$

(92) Example. How many wales per inch will there be in fabric made of number 16 yarn?

(93) Diameter of yarn is approximately $\frac{1}{21\sqrt{\text{Yarn number}}}$

So the diameter of No. 16 yarn is

$$\frac{1}{21\sqrt{16}} = \frac{1}{21 \times 4} = \frac{1}{84} = .0119$$

(94) The width of the wale is 4 times the diameter, or $4 \times \frac{1}{84} = \frac{1}{21}$ and the wales per inch are $1 \div$ (the width of the wale), $1 \div \frac{1}{21} = 21$ wales per inch.

(95) Example. A body rib machine makes fabric 10% wider than would be expected from the diameter of the yarn. How many wales per inch will the fabric have when yarn .013 inch in diameter is used (about number 13). The normal number of wales per inch would be (96) $1 \div$ (4 times the diameter of the yarn), or $1 \div 4 \times .013 = \frac{1}{.052} = 19.2$. But in this machine these 19.2 wales will cover 1.1 inches, because this machine makes the fabric 10% wider than would be expected. To find the wales per inch divide 19.2 by 1.1 and the wales per inch are 17.5.

(97) Example. A yarn coils 21 turns per half-inch (about number 4). How many wales should be expected in the fabric made of it?

(98) Wales $= 1/2$ Coils $\div 2 = 21 \div 2 = 10.5$

(99) Width of Fabric

The principal factors which affect the width of the fabric are the diameter of the yarn in it and the number of needles in the machine on which it was knit. Since most fabric is tubular, and the width is consequently considered to be the

width of the flattened tube, only half the needles in the cylinder are effective in producing that width.

Among the less important factors which affect the width of the fabric are the elasticity of the yarn, the tension under which the yarn is fed and the fabric rolled, the subsequent treatment, such as washing, drying, steaming, etc. These factors have not been investigated with sufficient thoroughness to facilitate calculations concerning them; so allowance must be made for them. The calculations apply to the widths delivered by the machine.

Each needle makes a wale, and a wale is four diameters of yarn in width; so the width of the fabric is four times the diameter of the yarn multiplied by the effective number of needles.

(100) Allowances, not always made here, may be 10% less than the calculated width for ribbers, loop-wheel, and single-set latch-needle machines, and 10% more for body rib machines.

(101) Example. A machine has 500 needles in the cylinder and is knitting yarn .015 inch in diameter (about number 10 yarn). What theoretical width of fabric is to be expected? 4 (diameters in wale) x .015 (diameter) x 250 ($\frac{1}{2}$ needles) = 15, the theoretical width in inches of the fabric to be expected.

(102) Example. How many needles are needed in a cylinder to make fabric 14 inches wide (theoretical) with yarn .018 inches in diameter (about number 7 yarn)?

(103) The width of a wale is .018 x 4 = .072

(104) The effective number of needles is 14 ÷ .072 = 194
The whole number of needles is 194 x 2 = 388

(105) Example. A latch-needle cylinder 4 inches in daimeter and containing 175 needles is to be used for making tubular bandages with yarn coiling 45 turns per half-inch (about number 18 yarn). How wide will the uncut bandage be?

(Needles)		($\frac{1}{2}$ Coils)		(Width)
175	÷	45	=	3.89

The actual width proved to be 4 inches.

(106) Example. A circular machine has 400 needles. What theoretical width of fabric may be expected with number 16 yarn?

(107) The diameter of 16 yarn is

$$\frac{1}{21\ \sqrt{\text{Number}}} = \frac{1}{21\ \sqrt{16}} = \frac{1}{21 \times 4} = \frac{1}{84} = .0119$$

(108) The width of the fabric = 4 x Dia. of Yarn x $\frac{1}{2}$ needles

$$= 4 \times \frac{1}{84} \times \frac{400}{2} = \frac{200}{21} = 9.5$$

(109) Example. What difference in the width of the fabric will be made by changing from number 20 yarn to number 24 yarn?

(110) $\frac{1}{2}$ Coils for number 20 yarn = $10.5 \times \sqrt{20} = 10.5 \times 4.47 = 46.93$

(111) $\frac{1}{2}$ Coils for number 24 yarn = $10.5 \times \sqrt{24} = 10.5 \times 4.9 = 51.45$

Since the thickness of the yarn decreases as the number of coils increases the width of the fabric will be inversely as the number of coils. That is, the widths with 20 yarn and 24 yarn will be as 51.4 is to 46.93, respectively. For convenience consider the coils to be 51 and 47. $47 \div 51 = .92$. Therefore, the fabric will be approximately 8% narrower with the 24 yarn than with the 20 yarn.

Notice that when, as in this case, the calculation applies to relative widths on any one machine the variation due to the machine itself is eliminated. The case is different when we do not use relative widths. For instance

(112) Example. What are the specifications for a machine to make rib fabric 16 inches in width (of flattened tube) with number 14 yarn?

(113) Since a body rib machine generally makes the fabric 10% wider than the theoretical width, divide 16 by 1.1 to get the theoretical width.
$16 \div 1.1 = 14.5$

(114) The number of needles = Width of fabric x $\frac{1}{2}$ Coils.

(115) $\frac{1}{2}$ Coils = 10.5 Yarn number = $10.5 \times \sqrt{14} = 10.5 \times 3.74 = 39.27$.

	(Width)		($\frac{1}{2}$ Coils)		(Needles)
(116)	14.5	x	39.27	=	570

(117) Cut = $\frac{1}{2}$ Coils $\div 4.29 = 39 \div 4.29 = 9.1$, say 9 cut.

(118) Thickness of Fabric

The thickness of flat fabric is two diameters of the yarn of which it is composed, and the thickness of rib fabric is four diameters. A convenient conception of the thickness is obtained by the recollection that rib fabric is as thick as one wale is wide, and flat fabric is half that thickness. Generally it is more desirable to use the thicknesses per inch than the thickness of a single piece of cloth. In that case it should be remembered that, for rib fabric, as many thicknesses will occupy an inch as there are wales per inch. For flat fabric, twice as many thicknesses will be required.

(119) Example. A cutting table is piled 1 foot high with rib fabric made from number 28 yarn. How many thicknesses of fabric are there in the pile?

Number 28 yarn coils about 56 turns to the half-inch, and the number of thicknesses per inch is half the number of coils or 28. So in twelve inches there will be 12 times 28 thicknesses, or 336.

(120) Example. Five inches depth of fabric is the limit for a cloth cutter. How many thicknesses of 28 gage balbriggan (flat-work) made from number 20 yarn will it cut?

The number of thicknesses per inch is the same as the number of coils per half-inch.

(121) $\frac{1}{2}$ Coils = $10.5 \sqrt{\text{Yarn number}} = 10.5 \times \sqrt{20} = 10.5 \times 4.47 = 47$. The number of thicknesses in 5 inches = $5 \times 47 = 235$.

(122) Example. A roll of rib cloth is $23\frac{1}{2}$ inches in diameter. The yarn coils 54 turns in half an inch (about number 26). How many layers of the tube of fabric are there on the roll?

Since we have no idea of the compression, figure without that. (123) The single thicknesses per inch of the fabric are $\frac{1}{2}$ Coils ÷ 2. (124) The double thicknesses are $\frac{1}{2}$ Coils ÷ 4 = 54 ÷ 4 = 13.5. The radius of the roll is $23\frac{1}{2}$ ÷ 2 = 11.75. The number of layers is 13.5 x 11.75 = 158.5. A count showed the number of layers to be 179; that is 20, or $12\frac{1}{2}$% more than the result of the calculation.

(125) Courses Per Inch

If the knitter is told that the courses per inch are closely related to the wales per inch, and therefore to the diameter of the yarn, he is likely to bristle up and challenge the statement, on the ground that he can adjust his machine to run almost any number of courses that he chooses. But if we ask him whether he has ever looked for a relation between the courses and wales, he is likely to answer that he never thought of such a thing, and that he does not see what good it would do, anyway. If we can induce him to put down in two columns side by side the courses and wales of the goods he is required to make, the relation of one to the other will be evident at a glance. The number of courses will be between one and two times the number of wales in almost any case, and in a large proportion of cases the number of courses will run between 1, and 1.5-times the number of wales, generally 1.25. Then how about that wide range of stitch adjustment? Why the range is there just the same, but any fabric made outside of the limits mentioned would not be considered good knitting. The long-stitch fabric would be shapeless and stringy, and the short-stitch fabric would be stiff. That is, for any one yarn, usage has limited the range of course to much less than the machine is prepared to make, and to considerably less than we have generally imagined was made. One who does not have access to machines in operation may use for his calculation (126) courses equals 1.25-times wales. Those who have access to the machines in operation or to a line of knit fabric may find their ratio by observation.

(127) Example. How many courses per inch may be expected in fabric made of number 25 yarn?

(128) The yarn diameter $= \dfrac{1}{21 \sqrt{No}}$

$$= \frac{1}{21 \sqrt{25}}$$

$$= \frac{1}{21 \times 5}$$

$$= \frac{1}{105}$$

(129) The wales are 4 times the diameter in width $= \dfrac{4}{105}$; so the number of wales per inch $= \dfrac{105}{4} = 26.25$.

(130) The courses are generally 1.25 times the wales, so the courses $= 26.25 \times 1.25 = 33$.

(131) Example. A yarn coils 42 turns to the half-inch (about number 16). How many courses may be expected in the fabric made from the yarn?

(132) The coils per inch divided by 4 equal the wales per inch; so (133) the coils per one-half inch divided by 2 equal the wales per inch, $= 42 \div 2 = 21$. The (134) courses per inch may be expected to be between 1 and 1.5-times the wales, probably 1.25-times; so the courses to be expected are between 21 and 32, and probably 26.

(135) Example. A yarn coils 44 turns to the half-inch (about number 18). What is the highest number of courses to be expected?

(136) The number of wales is the number of coils per half-inch divided by 2, and (137) the highest number of courses is 2-times the number of wales; so 44 is the highest number of courses to be expected.

(138) Example. A mill is running number 9 yarn, and is reported to be making fabric with 14 courses per inch. Is the mill making good fabric?

(139) The yarn diameter is

$$\frac{1}{21 \sqrt{No}} = \frac{1}{21 \sqrt{9}} = \frac{1}{21 \times 3} = \frac{1}{63}$$

(140) The number od diameters per inch is $1 \div$ the diameter, or 63. (141) The number of wales is $\frac{1}{4}$ of the diameters per inch, and (142) the number of courses for what is considered good fabric is 1.25-times the wales; so $63 \times 1.25 \div 4 =$ the number of courses to be used as a criterion $= 20$.

(143) Fabric which is considered sleazy has the same number of courses as

wales; which number, in this case, is $63 \div 4 = 16$. Since 14 courses is less than either of these - far less than 20, and even less than 16, considered to be the limit for looseness - the fabric cannot be pronounced good.

(144) Example. A government specification calls for fabric having 18 wales and 28 courses. Is the specification reasonable, and if so what will be the character of the fabric?

Courses divided by wales = $29 \div 18 = 1.56$. The specification is reasonable, since the limit of the ratio is approximately 2. The fabric is on the heavy side, for a ratio of 1.25 represents good average practice.

(145) Stitches Per Foot of Yarn

Consider a piece of hosiery yarn by itself, and it is difficult to conceive of a definite number of stitches in connection with it. Indeed, one is apt to say, "Why, we can use it with almost any number of stitches." But we begin to change our opinion on that subject when we consider the same piece of yarn in connection with a machine in operation. Submit that yarn to a knitter who is running a slightly heavier yarn, and he will say, "Why, yes; I can probably run that yarn on my machines by tightening the stitch." He knows by experience that since the yarn is lighter than what he is running he must tighten the stitch; that is, he must make each loop shorter, and thereby make more stitches per foot of yarn. In other words, in the actual use of the yarn he realizes that as the diameter of the diameter of the yarn decreases the number of stitches per foot must increase; but he almost never appreciates the dependability of that rule. Indeed, one who has not investigated the subject is not in a position to appreciate it; for seeing is believing. Some one will say, "But the rule cannot be dependable for I can change the stitch to a considerable extent with any one yarn and still make satisfactory fabric." Yes, but each fabric will have different characteristics, and for any one yarn there is a certain stitch which will give those characteristics. Now what is more important for advancement than the ability to duplicate a performance. The steel maker who made every lot of steel different would have to go out of business; on the contrary, ability to duplicate what he had made would be an important reason for keeping him in business He might make many different grades of steel; but he should be able to duplicate any one of them. And how could he do it, if not by duplicating every condition involved in the process? Is there any principle better fixed than the necessity of duplicating the influencing conditions in order to duplicate results? Therefore, it ought to be evident that, for any particular characteristic of knit fabric, the stitches per foot of yarn are closely related to the diameter of the yarn. The knitter may determine that relation for each different kind of fabric which he makes, and thereafter he has a dependable rule for the duplication of the fabric, as far as the stitches per foot of yarn are involved.

But how do we know that the rule holds for yarns which differ considerably in diameter? By observation. If one yarn has a certain number of stitches, the yarn twice the diameter will have half the number of stitches for fabric of the same characteristics as the first fabric. Possibly, more refined observations will show some variation from this rule, but there is no indication of sufficient variation to disturb its usefulness.

Since the stitches per foot of yarn increase as the yarn becomes finer, it is evident that the diameters of yarn per inch, or coils per half-inch, are more convenient units of reference than the diameter of the yarn, both because the relation is direct instead of inverse, and because the diameter is too small for convenient computation.

(146) Example. A yarn which coils 35 turns to the half-inch (about number 11) is run on a ribber at 33 stitches per foot of yarn. At what number of stitches should a yarn be run which coils 47 turns per half-inch (about number 20)?

The number of stitches is proportional to the number of coils, so
$33 \times \frac{47}{35}$ = the required number of stitches = 44.

(147) It will be noticed that the number of stitches is only a little less than the number of coils per half-inch; so for slightly heavier fabric, the number of stitches may be made the same as the number of coils per half-inch. This is a convenient relation to remember.

A good rule for rib fabric is, (148) Stitches per foot $= \frac{1}{2}$ Coils $\div$ 1.07. The fabric will have 25% more courses than wales.

(149) Example. A yarn coils 42 turns per half-inch (about number 16). What stitch is suitable for rib work? $42 \div 1.07 = 39$.

On rib machines the stitches are counted on only one set of needles, so half of the stitches are left uncounted. Consequently, for any one yarn, the number of stitches per foot is twice as much for flat work as for rib work. There is no difference in the appearance of the face of the goods provided the rib fabric is properly made. The flat-fabric rule corresponding to the one just given is

(150) Stitches per foot $= \frac{1}{2}$ Coils $\div$ .54.

(151) Example. A yarn coils 42 turns per half-inch (about number 16). What stitch is suitable for flat work? $42 \div .54 = 78$.

(152) Example. A yarn .015 inch in diameter (about number 10) is used for making flat fabric with 62 stitches per foot of yarn. How many stitches should be used with a yarn .011 inch in diameter (about number 18)?

Since the smaller yarn will have the larger number of stitches, we multiply the given number of stitches by the diameter of the larger yarn and divide that product by the smaller diameter.

$$62 \times .105 \div .011 = 85.$$

In these calculations involving reduction from a given number of stitches, the actual diameter of the yarn is not necessary but relative diameters are sufficient. For instance, diameters by the specific-gravity method may be used. But when the number of stitches is to be derived from the diameter of the yarn, then the actual diameter is necessary for dependable results. For instance:

(153) Example. The diameter of a yarn is .01 inch (about number 23). At what number of stitches will it run well for flat work? A good rule is

(154) Stitches = 1 ÷ 1.07 x Diameter
= 1 ÷ 1.07 x .01
= 1 ÷ .0107
= 94, The number of stitches for flat work.

When the stitches per foot for rib fabric are to be determined from the diameter of the yarn, the method is the same as for flat fabric, but the constant is different, because we count the stitches on one set of needles only. The number of stitches for flat fabric may be derived and divided by 2, or the formula for rib fabric may be used, namely,

(155) Stitches = 1 ÷ 2.14 x Diameter.

(156) Example. Take the same yarn as in the above example, namely .01 inch in diameter (about number 23). What number of stitches will be satisfactory for rib work?

Stitches = 1 ÷ 2.14 x .01
= 1 ÷ .0214
= 47, The number of stitches for rib work.

The least convenient means of determining the stitches is by the number of the yarn. A good formula for rib fabric is

(157) Stitches = $9.8 \sqrt{\text{Yarn number.}}$

(158) Example. What is a good number of stitches per foot for rib work for number 25 yarn?

$$\begin{aligned} \text{Stitches} &= 9.8 \sqrt{25} \\ &= 9.8 \times 5 \\ &= 49 \end{aligned}$$

For flat work, the constant is 20, instead of 9.8.

(159) Example. What is a good number of stitches per foot for flat work for number 16 yarn.

$$\begin{aligned} \text{Stitches} &= 20 \sqrt{16} \\ &= 20 \times 4 \\ &= 80 \end{aligned}$$

(160) Weight Per Square Yard for Change of Yarn and Proprotional Change of Stitch

When the stitch conforms to the size of the yarn the weight variation is inversely as the coils, and (161) the weight in pounds per square yard of rib fabric is about 19 ÷ $\frac{1}{2}$ Coils: the weight of flat fabric is half that.

(162) Example. A yarn coils 102 to the inch (about number 24). What is the

weight per square yard of rib fabric made of it?

$$38 \div 102 = .373 \text{ lbs. sq. yd.}$$

(163) Example. What is the weight per square yard of rib fabric made of number 16 yarn?

In this case it is convenient to solve by means of the yarn number instead of the coils for 16 has a simple square root.

(164) $\text{Weight} = 1.8 \div \sqrt{\text{Yarn number}} = 1.8 \div \sqrt{16} = 1.8 \div 4 = .45$

(165) Example. What is the number of yards per pound of rib webbing $1\frac{1}{2}$ inches wide made of number 14 yarn?

(166) $\frac{1}{2} \text{ Coils} = 10.5 \sqrt{\text{Yarn number}} = 10.5 \sqrt{14} = 10.5 \times 3.74 = 39.27.$

The weight formula transformed gives (167) the number of yards per pounds of strips one inch wide = $\frac{1}{2}$ Coils x 1.9. Consequently (168) the yards per pound for strips of other width are $\dfrac{\frac{1}{2} \text{ Coils} \times 1.9}{\text{Width of strip in inches.}}$ In this case

(169) $\text{Yards per pound} = \dfrac{39.27 \times 1.9}{1.5} = 49.7.$

A carefully conducted test gave 50 yards per pound.

(170) Example. What is the weight per square yard of flat fabric made of number 28 yarn?

For 28 yarn the number of coils per half inch is 56.

(171) Weight per square yard = 19 ÷ dia. inch ÷ 56 = .17.

(172) Weight Per Square Yard for Change of Yarn Without Change of Stitch

It is customary to change the stitch when the number of the yarn is changed; but occasionally the yarn number is changed without change in stitch. In that case, for finer yarn both the number of courses per inch and the weight per square yard is decreased, and for coarser yarn both these quantities are increased. The change in the weight is inversely proportional to the yarn number.

(173) Example. A manufacturer has been running number 19 yarn. He finds that some of his machines were supplied with number 11 yarn by mistake. What effect will that have on the weight per square yard of the goods made by those machines?

The weight of the new goods will be to the old, as the old yarn is to the new. The old yarn is 10 and the new yarn is 11. 10 ÷ 11 = .91. The fabric is 9% scant in weight.

[illegible]

(174) Example. Goods made of number 12 yarn are supposed to be kept within 5% either way of the weight per yard. If all other conditions remain constant, how much variation is allowable in the yarn number?

The allowable weight may be 95% or 105% of the specified weight. Therefore, the allowable range in yarn sizes will be 12 divided by each of these proportions.

$$12 \div .95 = 12.6$$
$$12 \div 1.05 = 11.4$$

The allowable variation is approximately half a count either way.

(175) Strength of Fabric

The strength of the fabric for one kind of yarn depends on the number of threads that stand the stress and the size of the threads. Since the wales tend to come together, and since the number of wales depends on the size of the yarn, the number of threads that stand the lengthwise stress is determined practically altogether by the size of the yarn. The crosswise strength, however, involves the number of courses, which in turn depends on the number of stitches per foot of yarn, and this number is variable to an extent. However, for commercial knit goods the proportion of courses to wales of 5 to 4, on which the formulas are based, gives satisfactory results. For special fabrics the reader may derive his own formulas. Since fabric does not present definite breaking areas, we cannot express the strength per unit of area, so the strength is expressed for a unit of width, namely for a strip one inch wide. For longitudinal strength the strip is cut along the wales, and for transverse strength it is cut along the courses.

The proportional longitudinal and transverse strength of the fabric is seen by inspection. Take the case of fabric in which the courses are to wales as 5 is 4. In flat fabric two threads stand the stress in each wale, whereas in nearly any case there is only one thread per course (multiple-thread work excluded). Multiplying the wales by 2 to get the relative strength, we have for (176) flat fabric, longitudinal strength is to transverse strength as 8 is to 5. For rib fabric we have to multiply the wales by 2 again in order to account for the loops on the back, so (177) for rib fabric the relative strength is as 16 is to 5. Consequently, the two fabrics have the same strength crosswise, but the rib fabric is twice as strong lengthwise as the flat fabric.

(178) Example. What is the strength of rib fabric made of number 16 cotton yarn?

Solve first with the yarn number, since the square root of 16, namely 4, is extracted by inspection.

(179) Longitudinal strength $= 286 \div \sqrt{\text{Yarn number}} = 286 \div \sqrt{16} = 286 \div 4 = 71\frac{1}{2}$ lbs per inch of width.

(180) Transverse strength $= 89 \div \sqrt{\text{Yarn number}} = 89 \div \sqrt{16} = 89 \div 4 = 22\frac{1}{4}$ lbs. per inch of width.

Solve now by means of the coils per half-inch, which are 42 for 16 yarn.

(181) Longitudinal strength = 3000 ÷ $\frac{1}{2}$ Coils = 3000 ÷ 42 = $71\frac{1}{2}$.

(182) Transverse strength = 938 ÷ $\frac{1}{2}$ Coils = 938 ÷ 42 = $22\frac{1}{4}$.

It is frequently desirable to know what size of yarn is necessary to make fabric of a specified strength.

(183) Example. What size yarn is necessary to make rib fabric having tensile strength of 70 pounds, per inch of width, along the wales?

(184) Yarn number = 81,625 ÷ (Tensile strength)^2
= 81,625 ÷ 70 x 70
= 81,625 ÷ 4900
= 16.65 Say, 16 yarn.

(185) Production of Knitting Machines

The production is generally given in pounds, altho it is sometimes given in linear yards, squareyards, and in dozens or dozen pairs of the articles manufactured. When the unit is dozens, the description of the article must be given, for it makes considerable difference whether the article is for adults or children.

The production in pounds is found by finding the weight in pounds of the length of yarn consumed by the machine. The machine in question, according to its diameter, revolutions, feeds, cut, and stitches per foot of yarn, draws in a certain length of yarn. Find what that length is, and its weight in pounds in the production. Altho the problem is simple, it contains so many factors, that one may become confused unless each factor is taken at a time. That method is followed here. Then all the factors are combined.

(186) Cylinder Diameter and Pounds Production

(187) Example. A 14-inch cylinder knits 30 pounds of fabric in a day. How many pounds will be knit by an 18-inch cylinder running at the same number of revolutions per minute?

When other conditions are the same, the production is proportional to the diameters of the machines. In this case $\frac{18}{14}$, and the production of the 18-inch cylinder = 30 x $\frac{18}{14}$ = 38.6

(188) Example. A 16-inch cylinder makes the goods too narrow. It is proposed to use a 17-inch cylinder, and to run it at the same number of revolutions. What will be the change in production?

Since the proposed cylinder is larger than the one in use, the change will be an increase, and the amount of the increase will be in proportion to the

cylinder sizes, namely as 17 : 16. $17 \div 16 = 1.06$. The increase in production will be 6%.

(190) Example. A mill making piece goods is running 40 cylinders 26 inches in diameter. In case 30-inch cylinders were used and run at the same number of revolutions, how many 30-inch cylinders would be required to keep up the production?

The increase in the production would be as 30: 26; so that the number of cylinders required would be as 26: 30, which in this case would be $40 \times \frac{26}{30} = 35$.

(191) Feeds and Pounds Production

Theoretically, the production of a knitting machine is proportional to the number of its feeds; that is, a machine with 4 feeds will produce twice as much as a machine with 2 feeds. But in practice the machine with 4 feeds will have to be stopped twice as often to piece the yarn. When the yarn is well wound on large bobbins or cones, this extra stoppage may be negligible for small differences in the number of feeds; but for large differences the stoppage is considerable. However, in any case, the stoppage to piece ends is generally provided for in the lost-time item; and that is usually estimated, because the conditions are special rather than general.

(192) Example. A 4-feed machine has room for another feed. What increase in production may be expected if it is equipped with another feed?

The production is proportional to the number of feeds, and that proportion is as 5 : 4; $5 \div 4 = 1.25$; therefore, a 25% increase may be expected.

(193) Example. A mill equipped with 400 feeds is making 5,000 pounds of webbing a day. How many extra feeds will be required to make 6,000 pounds per day?

$400 \times \frac{6000}{5000} = \frac{2400}{5}$ = total number of feeds needed = 480. So 80 extra feeds will be required.

(194) Speed and Pounds Production

The speed has a direct influence on the production; that is, the production is proportional to the speed, provided that the latter is not excessive for the conditions. If the cylinders are untrue, the needles are not properly spaced or aligned, the stopping devices are inadequate, etc., then increase in speed may actually decrease the production by causing excessive stoppage; but when the machines are in good condition, a considerable range of speed is feasible without much change in necessary stoppage.

(195) Example. A knit-goods manufacturer who is running his machines at an average speed of 35-revolutions per minute is advised that they may be run at 40. What increase in production will be occasioned by the contemplated change.

$40 \div 35 = 1.14$. The increase to be expected is 14%.

(196) Example. A mill manager has talked "more production" to his boss knitter until he dares not say any more on the subject; yet he wants more production but does not want to add to his equipment. He decides to tell the engineer to speed up the knitting-room main-line shaft on Sunday and say nothing about the change. The room is turning out 4,000 pounds of goods, and an increase of 200 pounds will be satisfactory. The shaft is making 180 turns. How many turns should it make to give the desired increase in production?

$$\underset{\text{(Original turns)}}{180} \times \frac{\overset{\text{(Required production)}}{4200}}{\underset{\text{(Original production)}}{4000}} = 189, \text{ the required number of turns.}$$

(197) Cut and Pounds Production

The cut - needles per inch- affects the production in direct proportion; that is, 11 cut produces 10% more than 10 cut, of course when other conditions are unchanged. This would not be the case if the yarn was not looped as it is drawn in; since the needle speed is not changed, and since we draw one more stitch in an equal time with the 11 cut than with the 10 cut, 10% more yarn is drawn into the machine.

(198) Example. A manufacturer learned that he could make an improvement in the appearance of his goods, and not encounter any disadvantage, by using a finer cut; so he changed from 11 cut to 12 cut. Unexpectedly his production increased. What was the amount of the increase?

$12 \div 11 = 1.09$. The amount of the increase was 9%.

(199) Example. After a mill has been sold up for a season, it is discovered that the yarn is too heavy for the gage, but the yarn cannot be changed. In order to avoid excessive waste, it is contemplated to change the gage from 20 to 18. How will that affect the production?

$18 \div 20 = .90$. The loss in production will be 10%.

(200) Yarn and Pounds Production

Increase in the yarn number results in decrease in the pounds production. This is because the yarn number is an inverse measure of the yarn weight; that is, as the number runs higher the weight runs lower. Therefore, to use the yarn number in our weight calculations we have to use it as a divisor. We may either divide directly, or express the division as a fraction with the yarn number in the denominator.

(201) Example. A manufacturer who is in the market for number 18 yarn is offered a bargain lot of number 20 yarn and is in a position to substitute it without making any changes in equipment and operation. How will his production in pounds be affected?

We are calculating on a change from number 18 yarn, so 18 is our basis of calculation. The change in weight is inversely as the number of the yarn, so our other factor is $\frac{1}{20}$.

$18 \times \frac{1}{20} = .90$. Therefore the production will fall off 10%.

(202) Example. A mill using number 24 yarn knits 3,000 pounds of goods per day. A new lot of nominal 24 yarn is really $23\frac{1}{2}$. What effect will it have on the production?

$$\underset{\text{Nominal production}}{3000} \times \frac{\overset{\text{Nominal yarn}}{24}}{\underset{\text{Actual yarn}}{23\frac{1}{2}}} = \underset{\text{Actual production}}{3064.}$$

The production will be increased by about 64 pounds.

(203) Stitches Per Foot and Pounds Production

The stitches per foot of yarn affect the production inversely, as the yarn number does, and for the same reason; as the stitches per foot increase the amount of yarn used decreases.

(204) Example. In order to increase the number of courses in the fabric, the knitter is required to shorten the stitch from 74 to one foot of yarn, to 80. Thereafter the knitter is called to account for a falling-off in the production. How much of the falling-off can he lay to the change in stitch.

New production: old production $= \frac{1}{80} : \frac{1}{74}$

New production $=$ old production $\times 74 \div 80$
$= .925 \times$ old production.

Therefore, the knitter can lay $7\frac{1}{2}$% of the falling-off in the production to the change in stitch.

(205) Example. Some 4-inch machines which have been run at 45 stitches per foot of yarn are to be used to make sanitary tubing at 33 stitches per foot. How will the production be affected?

New production : Old production $= \frac{1}{33} : \frac{1}{45}$

New production $=$ old production $\times 45 \div 33$
$= 1.36 \times$ old production.

The production will be increased 36%.

(206) Time and Pounds Production

It should be understood without the saying that the production is proportional to the time the machine runs; so examples are not necessary to show the influence of time.

(207) General Solution for Pounds Production

We have seen that the production varies directly as the diameter of the machine, the feeds, the revolutions, the cut, and the time, and varies inversely as the yarn number and the stitches; and we have worked out special problems in each case, except for time, in which case problems were unnecessary. But how about the general case in which all the factors may vary? That is solved by a combination of all the special cases. We write:

Production varies as Diameter, Feeds, Revolutions, Cut, $\frac{1}{\text{Yarn}}$, $\frac{1}{\text{Stitches}}$, Time.

Expressed mathematically, that would be:

Production varies as, Diameter X Feeds X Revolutions X Cut X $\frac{1}{\text{Yarn}}$ X $\frac{1}{\text{Stitches}}$ X Time.

Or production varies as

$$\frac{\text{Diameter X Feeds X Revolutions X Cut X Time}}{\text{Yarn X Stitches}};$$

or the actual pounds production =

$$\frac{\text{Diameter X Feeds X Revolutions X Cut X Minutes}}{\text{800 X Yarn X Stitches}}$$

Care should be exercised to use the right units.

The diameter is inches measured on the needle line,
The revolutions are per minute,
The cut is needles per inch,
The yarn is cotton number,
The stitches are cylinder stitches per foot of yarn.

The number 800 - called the constant - is necessary to adjust the relationship of the units used. For instance, if the time unit is hours, the constant must be divided by 60, making it 13.3; and if the time unit is ten-hour days, the constant must be divided by 600, making it 1.33. Anyone may derive his special formula from this general formula.

A word of warning in respect to this formula may not be out of place. A couple of knitters, convinced that guesses - their guesses - were superior to calculations, tested this formula one time by actual trial and found it to be wrong, much to their satisfaction; and they told many of their friends about it, not realizing that they had confessed their inability even to conduct an experiment accurately, much less than to guess accurately. And mind you, they were "practical knitters", too; the kind that say, when asked a question, "I don't know; but I will make a piece of cloth and find out." This pair demonstrated that, in spite of "making a piece," they found out what was not so. In short,

the formula is absolute: what discrepancy there may be between the calculated and actual performance of the machine will be either error in the use of the formula or inaccuracy in the determination of the factors.

(209) Example. What will be the production under the following conditions:

Diameter of cylinder	16 inches
Feeds	6
Revolutions	44
Cut	11
Time 9 hours	540 minutes
Yarn	20
Stitches per foot of yarn	44

(210) $$\frac{\text{Diameter X Feeds X Revolutions X Cut X Minutes}}{\text{800 X Yarn X Stitches}} = \text{Production in pounds.}$$

$$\frac{16 \text{ X } 6 \text{ X } 44 \text{ X } 11 \text{ X } 540}{800 \text{ X } 20 \text{ X } 44} = 35.6$$

(211) Pounds Production for Multiple-Thread Work

When the work is multiple thread, the single equivalent yarn may be used if the stitches are alike; but for unlike stitches, the simplest method is to solve for the production of each yarn with its own stitch and to add the results. Backing threads are generally figured as a proportion of the face. For instance, flat fleeces run about 50% backing. The production of the face fabric is obtained by solving for the production with the face thread and then with the binder, or with the single equivalent thread if the stitches are alike. Then that weight is doubled to include the backing, or is increased by whatever proportion the backing is of the face fabric.

(212) Simple Solution for Pounds Production

Attention has been called to the inadequacy of the prevalent yarn-numbering systems for the knitter. In order to use the yarn number, the square root must be obtained, and that is general a decimal, inconvenient to use at best and out of the question for mental calculations. This is a serious obstacle to the advancement of the knitting industry, for most of its formulas are simple and they are particularly adaptable to mental solution. This inadequacy of the yarn-numbering system for the knitter is shown not only by its inconvenience in most cases, but by the rarity of the cases in which it is convenient. Of approximately 170 formulas available for the knitter's use, the yarn number is usable conveniently only once: that is in the calculation of the production in pounds. In the other cases, its square root must be used. We come to the consideration of that exceptional case now.

Efficiency is one of the most important questions in life, and the indications are that it will ever increase in importance; and production is one of the most important elements of efficiency. Even the price of a machine is a secondary consideration to its capacity; and when we ask the operator of a machine, "What is

this machine capable of producing?" and he says, "Well, I don't know, but I am getting 40 pounds a day from it," we are not seriously impressed with that operative's knowledge of his business. Especially, if to supply this information, the rule for the capacity of knitting machines is the simple one in which the yarn number may be used just as it is - that is, without extraction of the square root. We come to that rule by contraction of the general production formula,

(213) Production in pounds =

$$\frac{\text{Diameter X Feeds X Revolutions X Cut X Minutes}}{\text{800 X Yarn X Stitches}}$$

Altho this is an absolute expression, it is too cumbersome for solution by inspection; so we must make some assumptions in order to reduce it to a simple form. The reader should know just what these assumptions are, so that he will not deceive himself in the use of the simple rule. Each item will be treated separately.

The needle speed of any one type of machine is - or should be - practically constant. That is, we have an agreed number of revolutions for the average size; smaller sizes are speeded down, to make the needle velocity practically the same on all sizes. In other words, as the diameter of the machine goes up, the revolutions go down; so for any one type of machine the product of the diameter and the revolutions is constant. Let us take body rib machines for which 35 revolutions of a 20-inch cylinder is good average practice. The product of the two factors is 700; so we may substitute 700 in the place of these two factors in the equation.

The number of feeds varies roughly according to the size of the machine, so we may adapt our formula to 1 feed, and multiply the result by the number of feeds on the particular machine under consideration.

The cut and the stitches are generally both increased or decreased proportionately according to the yarn used; so they may be displaced by a constant, as in the case of the diameter and the revolutions.

The time may be made anything that we choose: ten hours is a good time to take, because it facilitates percentage deduction both for a nine-hour or eight-hour day, and for lost time.

The only variable factor left is the yarn number in the denominator of the fraction.

It is not necessary to give the reduction of the constant. For good average practice for rib body machines it is 131; so our expression is,

(214) Production of rib machine = 131 ÷ Yarn number.

This is the convenient form of the expression for the production of knitting machines. It is simpler, and generally, more reliable, than similar rules in use for most other machines. It is based on the assumption that the needle

speed is standard, and that the cut and the stitches per foot of yarn have a standard relation to the size of the yarn. That relation in this case is that the (215) stitches $= 9.8\sqrt{\text{Yarn number}}$, and (216) Cut = Stitches ÷ 4, which relations will be found to conform to good average practice. If these relations are exactly maintained, this short rule is absolute, the same as the longer rule. If there is considerable variation from these conditions, the machine is not operating to good advantage. In the former case the rule is reliable as to the actual production; in the latter case it is an indicator of what should be expected if good average practice is followed.

(218) Example. What is the ten-hour capacity of a body rib machine having 8 feeds and running number 24 yarn?

131 ÷ 24 = The capacity of one feed = 5.5, so the capacity of the eight feeds is 5.5 x 8 = 44.

(219) Example. The ten-hour capacity of a machine is 44 pounds, but the actual production is 35 pounds. What is the lost time in hours and in percentage of the whole time?

44 - 35 = The loss in pounds = 9.

9 ÷ 44 = The proportional loss in pounds = .204, practically 20%. The loss in time will be the same, so the machine has been standing idle for two hours out of the 10.

The capacity of a knitting machine, and the rule for it may be obtained from observation of the machine. For instance:

(220) Example. An 8-feed rib machine using number 22 yarn was timed for 30 minutes, during which interval it made 2.4 pounds of cloth. There were 4 stops which totaled 3 minutes and 20 seconds. What is the 10-hour capacity of this machine?

The actual running time was 30 minutes minus 3.33 minutes, which equals 26.67 minutes.

There are 600 minutes in 10 hours.

(Pounds knit in 26.67 minutes)		(Minutes in day)	(Minutes in Test)		(Pounds in day)
2.4	x	600	26,67	=	54

(221) Example. What is the capacity rule for this machine? The capacity per feed is 54 ÷ 8 = 6.75.

(222) Since capacity = Constant ÷ Yarn

$$\begin{aligned}\text{Constant} &= \text{Capacity X Yarn}\\ &= 6.75 \text{ X } 22\\ &= 148.5;\ \text{say } 148\end{aligned}$$

The rule is, Capacity = $\frac{148}{\text{Yarn number}}$

Attention is called, in this connection, to the fact that the rule is not intended for change of yarn on any one machine, without corresponding change of cut. For instance, the constant 148 would hold for this machine and number 26 yarn, only if the cut is made correspondingly finer; which is not likely to be the case. In other words, the rule is not intended for changes of yarn in any one machine without corresponding change of cut; but it is intended to give a a reliable idea of what may be expected of knitting machines in general. The machine in question was in a mill which prided itself on high speed. If the other machines in the room were operated at the same needle speed and at a corresponding stitch, then this constant, namely 148, would apply for each machine.

(223) Example. If the average capacity constant is 131 and a mill shows a capacity constant of 148 on account of higher speed, what is the gain in production, provided there is no increase in the lost time?

148 - 131 = 17
17 ÷ 131 = .13. The gain is 13%

The capacity formula for flat-work, loop-wheel machines is,

(224) Capacity = 161 ÷ The yarn number.

It is interesting in this connection to recall the arguments of the respective champions of the loop-wheel and latch-needle machine. "My machine will produce more goods than yours will." "But your cut is different." "Well, your yarn is different." Of all the non-conclusive arguments - most are such - this was one of the leaders. The trouble was that there was no basis of comparison. Such questions are soon settled by the calculations just given, or similar ones.

(225) Example. The capacity constant of a loop-wheel machine is 161 and it has 4 feeds. The capacity constant of a rib machine is 131 and it has 6 feeds. Which will turn off the greater weight of goods in a given running time with a given yarn, and what is the percentage gain of the one over the other?

Since the yarn is the same, the relative production is as the products of the respective constants and feeds.

For the loop-wheel machine we have 161 x 4 = 644.
For the rib machine we have 131 x 6 = 786.

The rib machine leads, and the percentage gain is 142 ÷ 644, or 22%.

(226) Example. What production in pounds per feed should be expected of a flat-work loop-wheel machine with number 20 yarn?

161 ÷ 20 = 8.05. Say, 8 pounds.

(227) Example. A mill spins 2,000 pounds of number 20 yarn per day. How

many 8-feed rib machines will be required to knit the product?

The single feed, 10-hour production rule for a rib machine is 131 ÷ yarn number. 131 ÷ 20 = 6.55. Allow 20% lost time. Then each feed will knit in pounds 6.55 x .80 = 5.24. So an 8-feed machine will knit in pounds 5.24 x 8 = 41.92. The number of machines required will be the quantity of yarn to be knit, namely, 2,000, divided by the capacity of each machine, namely, 41.92. 2,000 ÷ 41.92 = 48, the number of 8-feed rib machines required.

(228) Example. A rib machine runs 10 hours per day; its average daily production is 35.85 pounds; a half-hour run with no lost time shows it would produce 55.9 pounds in ten hours actual time. How much time does it lose?

Theoretical production		Actual production		Lost production
55.9	-	35.85	=	20.05
Lost production		Theoretical production		Per cent of lost time
20.05	÷	55.9	=	.36

(229) Linear-Yards Production

The production in linear yards is ascertained by dividing the number of courses made by the machine by the number of courses per yard. The number of courses made by the machine is the revolutions per minute, multiplied by the number of feeds, multiplied by the number of minutes taken, say 540, which is the number in a nine-hour day. The number of courses per yard is the courses per inch in the fabric multiplied by 36, the number of inches in a yard.

(230) Example. A 17-inch machine having 6 feeds makes 41 revolutions per minute, and the fabric has 21 courses per inch. How many linear yards will it make in 9 hours actual running time?

Revolutions X Feeds X Minutes = 41 X 6 X 540 . . (1)
Courses per inch X 36 = 21 X 36 . . . . (2)

(1) ÷ (2) = 175.7, The linear-yards production.

(231) Square-Yards Production

The square-yards production is the number of stitches made in a given time divided by the number of stitches per square yard. (1), Multiply together the number of needles (Which produce face stitches - e.g., not dial needles), feeds, revolutions, and minutes; and, (2), divide (1) by the number of stitches per square inch multiplied by 1,296, the number of square inches in a square yard.

(232) Example. What is the square-yard production under the following conditions?

Needles in cylinder	754,
Feeds	4,
Revolutions	50,
Time 10 hours	600 minutes
Stitches per square inch	276

(Face) Needles X Feeds X Revolutions X Minutes = 754 X 4 X 50 X 600 . . (1)

Stitches per square inch X Inches per square yard = 276 X 1296 . . . . . (2)

(1) ÷ (2) = 252.8, The square-yards production.

When the speed, cut, and stitches per foot are standardized, the problem is simple.

(233) Example. How many square yards per feed may be expected in 10 hours actual running time from a rib machine with number 16 yarn?

Number 16 yarn has 42 coils per half-inch. The production in yards is inversely proportional to the number of coils. In other words

(234) Square yards per rib feed for 10 hours

$$
\begin{aligned}
&= 760 \div \tfrac{1}{2} \text{ Coils} \\
&= 760 \div 42 \\
&= 18.1
\end{aligned}
$$

(235) Example. How many square yards per feed may be expected in 10 hours' actual running time from a flat-work, loop-wheel machine running number 16 yarn.

(236) Square yards per flat feed for 10 hours

$$
\begin{aligned}
&= 1869 \div \tfrac{1}{2} \text{ Coils} \\
&= 1869 \div 42 \\
&= 44.5
\end{aligned}
$$

(237) The General Knit Fabric Formula

(238) $$\frac{\text{Wales X Courses}}{\text{Weight X Number X Stitches}} = \frac{35}{18}$$

The wales and courses are the number per inch.
The weight is pounds per square yard.
The yarn number is the cotton count.
The stitches are per foot of yarn.

Care should be taken that the stitches per foot of yarn are the identical stitches which appear in the wales and courses. For instance, in rib knitting, it is customary to count the wales and courses which appear on only one side of the fabric. Then the stitches per foot should be those on the corresponding set of needles (for plain rib fabric, it makes no difference which set).

This formula is a necessary consequence of the structure of knit fabric and of the definitions of the factors involved; that is, the formula itself is exact; whatever error occurs will be from inaccurate factors or improper solution.

For those who think that the above expression is algebraic, the following expression, in the form of compound proportion, makes it arithmetic.

$$(239)\qquad \begin{matrix} \text{Wales} \\ \times \\ \text{Courses} \end{matrix} \; : \; \begin{matrix} \text{Weight} \\ \times \\ \text{Number} \\ \times \\ \text{Stitches} \end{matrix} \; : : \; 35 \; : \; 18$$

It is difficult to find a more satisfactory commercial formula in any industry. It may be used to solve for any factor when the other four are given; to check the results of fabric analysis; to verify fabric descriptions; etc., etc.

(240) Example. What is the weight per square yard of worsted fabric of the following description?

Wales	$16\frac{1}{2}$
Courses	24
Stitches per foot	50
Yarn number (cotton count)	6.76

$$(241)\qquad \frac{18 \times \text{Wales} \times \text{Courses}}{35 \times \text{Number} \times \text{Stitches}} = \text{Weight}$$

$$\frac{18 \times 16\frac{1}{2} \times 24}{35 \times 6.76 \times 50} = .60 = \text{Weight per square yard.}$$

(242) Example. A certain book gives the following specifications for a representative piece of rib fabric. Are these specifications consistent?

Yarn	24
Stitches per foot	48
Wales	25.72
Courses	32.16
Weight	.369

If they are consistent they will satisfy the general knit-fabric expression. For variety use the compound proportion form.

$$(243)\qquad \begin{matrix} \text{Wales} \\ \times \\ \text{Courses} \end{matrix} \; : \; \begin{matrix} \text{Weight} \\ \times \\ \text{Number} \\ \times \\ \text{Stitches} \end{matrix} \; : : \; 35 \; : \; 18$$

$$\begin{matrix} 25.72 \\ \times \\ 32.16 \end{matrix} \; : \; \begin{matrix} .369 \\ \times \\ 24. \\ \times \\ 48. \end{matrix} \; : : \; 35 \; : \; 18$$

The product of the means will equal the product of the extremes if the expression is satisfied.

$$25.72 \times 32.16 \times 18 = .369 \times 24 \times 48 \times 35$$
$$14888 = 14878$$

The discrepancy is less than one in a thousand, so the specifications satisfy the expression for all practical purposes.

The value of this kind of test may be judged from consideration of it applied to an analysis. Some of the factors can hardly fail to be right. Then whatever error there is in any of the remaining factors must be counterbalanced by a corresponding error in the rest of the remaining factors; and the chances are rare for such a coincidence; so the test has considerable value, even if no one of the factors can be verified. Of course the value of the test increases according to the increase in the number of factors verified: if all are verified, there is no need of the test.

(245) Winding

The time lost during winding is not susceptible of calculation. No one can calculate whether a girl will be slow or fast in tieing a knot or in replacing an empty cop or cone; nor how many lost ends, bad knots, or weak places the cone or cop will contain; nor how often belts must be laced; etc. Consequently, this lost time must be estimated. It is convenient to estimate it as a percentage of the daily running time. Sometimes it is estimated to be one hour a day, or ten per cent.

The capacity of the winder during actual running time is susceptible of very satisfactory calculation on account of the fact that most winders in use take an equal length of yarn per spindle in an equal time. That is, in a day a spindle of any of any particular winder will wind just as many yards of a No. 1 yarn as it will of a No. 2 yarn. Of course, that number of yards depends on the speed at which the winder is run. Each type of winder is supposed to run at a certain speed recommended by the maker; but in actual practice it is generally run at the speed dictated by the requirements of the user, so it is better not to depend on the conventional speed, but to take the yardage wound just as we find it.

If the capacity in yards suited our purpose the problem would be about as simple as it possible could be. The capacity of a certain winder would then be the fixed capacity per spindle multiplied by the number os spindles, of course discounted for lost time, according to the circumstances. But we want the capacity in pounds.

Suppose that we wind No. 10 yarn on one spindle continuously all day long, and find that 5 pounds were wound altogether. We know that No. 20 yarn has twice as many yards per pound, so that same spindle would wind $\frac{10}{20}$ of 5 pounds, or 2.5 pounds of No. 20 yarn. Similarly, if we multiply together the capacity with any known yarn and the number of that yarn and divide by the number of another yarn, we get the capacity with the other yarn. Evidently, we do not need to multiply the capacity and the known yarn every time, for it will always be the same. In this case it is $5 \times 10 = 50$. We need only remember that 50 divided by any yarn we want to use on that winder will give the capacity per spindle. This number, 50, is called the "winder constant."

(246) Example. A cone of No. 20 yarn was weighed. Winding from it was then begun; and the starting time, the stopping time, and the lost time were noted. After half an hour of actual running time the cone was found to have lost .55 of a pound. What is the winder constant?

In 10 hours the weight would have been 20 times as much, or 11 pounds. Then,

(Capacity)		(Yarn Number)		(Constant)
11	X	20	=	220. Consequently,

$$\frac{220}{\text{Yarn number}} = \text{Winder capacity in pounds per spindle.}$$

It is advisable to make a longer run in the derivation of the winder constant, because any error in the work is multiplied by 20 in this case.

(247) Example. The capacity constant of a certain winder is 220; how much No. 30 cone yarn will it wind per day per spindle?

(Constant)		(Yarn Number)		(Capacity)
220	÷	30	=	7.33

Deduct 5%, or .36, for lost time. 7.33 - .36 = 6.96; say, 7 pounds. If the yarn is wound from cops, deduct more lost time, because cops have to be replaced more frequently than cones; say 10% lost time. 7.33 - .73 = 6.6 pounds.

(248) Example. A two-sided, 40-spindle winder, the capacity constant of which is 183, winds 250 pounds of No. 24 yarn in 10 hours. What is the lost time?

(249) $\dfrac{\text{Constant X Number of Spindles}}{\text{Yarn Number}} = \text{Total winder capacity.}$

$\dfrac{183 \times 40}{24} = 305.$ Since the actual winding was only 250 pounds, the discrepancy in weight was 305 - 250 = 55. The proportion of lost time was as 55: 305, namely 18 per cent.

(250) Example. Conditions.

The winder capacity per spindle is 183 ÷ Yarn number.
The yarn is number 20, on cones.
The operator tends 18 spindles.
The lost time allowance is 3%.

What should the operator be paid per 100 pounds to bring the daily pay to $1.30?

(Lost time)		(Running time, percentage)
1. - .03	=	.97

$$\frac{\underset{\text{(Constant)}}{183} \times \underset{\text{(Spindles)}}{18} \times \underset{\text{(Running Time)}}{.97}}{\underset{\text{(Yarn)}}{20}} = 160$$, the number of pounds wound per day.

160 pounds is 1.6 hundred-weight; so the price to pay per 100 pounds in order to bring the daily pay to $1.30 is 1.30 ÷ 1.6 = .81; say , 80 cents per hundred.

(251) Fabric Analysis

Analysis of fabric to determine the yarn number, stitches per foot, weight per square yard, etc., affords one of the best exercises in fabric calculations. Unnecessary duplication of work may be avoided by an example analysis when involves most of the problem likely to occur. The following analysis, from actual practice, of a piece of flat fleece goods involves the methods used for single-thread work; two-thread work, with either like or unlike stitches; and backing thread work; so the reader may find it in the solution of most of the problems in the analysis of plain knit fabric.

(252) Rectifying the Sample

Altho the samples generally submitted to the analyst are small, it is advisable to make them rectangular along wales and courses, unless the sample is so very small that the necessary trimming would cut away too much material. The latter case is so special that it is not given in detail here, as it can be worked out by one who has mastered the general case.

Most knit fabric will ravel from either end; but fleeces (backing cloth), rib fabric, tuck work, and some other types ravel only from one end - the end which left the needles last - so it is advisable to determine which end ravels and to make one full raveling across from one boundary of the sample. A pointed instrument or stylus like a machinist's scriber, but with a more slender point, is useful for raveling. The other end of the sample should be raveled, to rectify it, if it will ravel; otherwise it should be cut along the first full course at that end.

The boundaries along the wales must be cut - preferable with keen slender shears - and care should be exercised to cut between wales and not into them. The wales are determined by the loops at the raveled end. If each end ravels the true needle wale may not be distinguishable from the sinker wale; but in that case either wale will answer, as long as it is considered as the guiding wale throughout the analysis. The end that ravels, or a selected one of two that ravel, is taken as the top of the sample; the right and left end and the bottom are determined thereby.

If the backing is put in at every second course, or if there is any other pattern feature, disregard of which would affect the result of the analysis, the sample should contain an integral number of patterns; for instance, an even number of courses when the backing is put in at every other course. In that case

an odd course must be raveled off.

(253) Weighing the Sample

An accurate balance is essential for fabric analysis, preferably one that weighs to thousandths of a pound, altho a grains scale will serve the purpose. It should be kept free from dust, corrosion, and rough usage. The sample should be weighed twice, and the results should agree; for, since the sample is to be raveled away, a mistake cannot be rectified by again reweighing the sample as a whole.

The sample in question weighed .00513 of a pound.

(254) Measuring the Sample

If the sample is rectangular, the area of it may be determined by multiplying the length by the breadth: if it is not rectangular, as may be the case on account of twist in the knitting, one of the long boundaries may be selected as the base, the distance between the two as the altitude, and, of course, the area will be the product of the two.

The sample in question measured in inches 3.15 in length by 3.62 in depth.

The dimensions in wales and courses should be counted before raveling is begun. The counting is generally done by means of a magnifier and the stylus. An inch aperture for the magnifier is advisable when much work is to be done. Otherwise a pocket pick glass with aperture $\frac{1}{2}$ by $\frac{1}{4}$ inch is satisfactory. An objection to the small glass is that it has to be moved frequently during the counting.

The sample in question has 72 wales and 85 courses.

Summary of Sample

Fabric - Blue, napped, double plush.

Size - 3.15 by 3.62 = 11.40 (area in square inches).

Stitches - 72 wales and 85 courses: 72 X 85 = 6120 stitches.

(255) Raveling the Sample

It is easy to say "ravel the sample"; but the performance is not always easy. Lint in the loops may impede their withdrawal; knots may refuse to come through; the material may be matted; the yarn may be tender; etc. The analyst must determine not to pull when the yarn refuses to come, but to remove the obstruction or to free the yarn in a way which will not break it nor distort the fabric.

In multiple-thread work care must be taken not to mix the different yarns. When the yarns are different in color or markedly different in size, material, or construction, there is not much danger of mixing them. In this case, since the fabric was dyed in the piece, the yarns were all one color; so there was danger of mixing the face yarns. The backing was heavy weight and soft twist, and the bends in it were, of course, different from those of the regular knitting loop, so it could be distinguished readily. The position of the yarn in the fabric is also a means of identifying it. The binder crosses the backing, and may readily be picked up for raveling by inserting the stylus between it and the backing. The face thread will generally remain in the fabric while the binder is being withdrawn, altho it passes through the same loops. A receptacle, such as a small box, should be provided for each yarn and labeled with the name of the yarn to avoid confusion, especially in view of the fact that the work may be interrupted by failing light or the close of the day.

One object of the raveling is to obtain sufficient yarn to give reliable weighings for the determination of the numbers of the respective yarns; so it may not be necessary to ravel the whole sample. Indeed, it is desirable to retain a piece of the sample for future reference.

When sufficient yarn has been raveled, each lot should be weighed, and the remnant, if any, and the total weight should equal the weight of the original sample.

The weights in the case in question were as follows:

	Weight	Per cent.
Face thread	.0014	27.7
Binder thread	.00125	24.7
Backing thread	.0024	47.6
Shrinkage	.00008	Negligible
Original weight	.00513	
		100.

(256) Measuring the Yarn

To measure the yarn a scale graduated preferably in inches and decimals thereof should be laid on the table. The box of ravelings to be measured should be brought within reach, and all other pieces should be moved out of reach. The piece of yarn should be grasped at each end, stretched as much as it would be on a yarn-numbering reel, as nearly as can be estimated, and measured by holding it near to the scale. It is almost necessary to have two pairs of tweezers, similar to the tweezers used to lift the balance weights. The fingers cannot grasp the yarn sufficiently near the ends to afford accurate measurement. A sufficient number of pieces of yarn should be measured to give a reliable average of the length of yarn across the sample. Ten is a desirable number to measure because the average can be seen by inspection of the total. When one lot of yarn has been measured, it should be carefully replaced in its box for future reference and put out of reach while the next lot is measured.

The measurements in the case in question were as follows:

	Face	Binder	Backing
	14.75		
	14.8	13.4	
	13.8	12.6	
	14.5	13.4	
	15.	11.5	
	14.5	12.5	5.6
	15.25	12.25	5.5
	13.6	13.5	5.
	15.	14.	5.
Total	130.9	103.15	21.1
Pieces measured	9.	8.	4.
Average length	14.54	12.89	5.27

(257) Lengths of Yarns in the Sample

The number of yards of any particular yarn in the sample is the number of yards in a course multiplied by the number of courses. Since the length in a course is generally recorded in inches it is necessary to divide the product just mentioned by the number of inches in a yard, namely, 36.

(258) Formula:

$$\frac{\text{Average length in course, in inches X Number of courses}}{\text{Inches in yard}} = \text{Yards in piece.}$$

The lengths of yarn in the sample in question were as follos:

Face thread $\frac{15.54 \text{ X } 85}{36} = 34.3$

Binder thread $\frac{12.89 \text{ X } 85}{36} = 30.4$

Backing thread $\frac{5.27 \text{ X } 85}{36} = 12.43$

(259) Determination of the Yarn Numbers

The number of the yarn is its length in yards divided by 840 times its weight in pounds.

(260) Formula:

$$\frac{\text{Yards of yarn}}{\text{840 X Weight of yarn in pounds}} = \text{Yarn number.}$$

[illegible]

[illegible]	[illegible]	[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

The numbers of the yarn in the sample in question were as follows:

Face thread $\dfrac{34.3}{840 \times .0014} = 29.1$

Binder thread $\dfrac{30.4}{840 \times .00125} = 29$

Backing thread $\dfrac{12.43}{840 \times .0024} = 6.17$

The grain (Cohoes) of the backing is $52 \div 6.17 = 8.43$. The backing was evidently $8\frac{1}{2}$ grain (Cohoes); and the face and binding were evidently nominal 30 cotton number, since commercial yarn is generally coarser than its number.

(261) Weight Per Square Yard of the Sample

To find the weight per square yard of the sample, divide its weight by its area in inches, which gives the weight of the fabric per square inch; then multiply that weight by the number of inches in a square yarn, namely 1296. The calculation is generally expressed as the weight of the sample multiplied by the relative area of a square yard to the sample; but the principle is the same in either case.

(262) Formula:

$$\frac{\text{Square inches in square yard}}{\text{Square inches in sample}} \times \text{Weight of sample} = \text{Weight per square yard of sample.}$$

The weight per square yard of the sample was as follows:

$$\frac{1296}{11.40} \times .00513 = .583$$

(263) Stitches Per Foot of Yarn

The stitches per foot of yarn are obtained by dividing the number of wales in the sample by the number of feet in the average raveling. The formula is derived as follows:

$$\text{Wales} \div \text{Feet of yarn} = \text{Stitches per foot.}$$

$$\text{Wales} \div \frac{\text{Inches in raveling}}{\text{Inches in foot}} = \text{Stitches per foot.}$$

$$\text{Wales} \div \frac{\text{Inches in raveling}}{12} = \text{Stitches per foot.}$$

(264) $\dfrac{\text{Wales} \times 12}{\text{Inches in raveling}} = \text{Stitches per foot.}$

The stitches per foot in the sample were as follows:

Face thread $72 \times \frac{12}{14.54} = 59.4$

Binder thread $72 \times \frac{12}{12.89} = 67.$

Backing (The backing in not knit in stitches).

(265) Wales and Courses Per Inch

The wales per inch are the number of wales in the sample divided by the width of the sample; and the courses are the number of courses divided by the depth.

Formulas:

(266) $\frac{\text{Wales in sample}}{\text{Length of sample in inches}} = \text{Wales per inch}$

(267) $\frac{\text{Courses in sample}}{\text{Depth of sample in inches}} = \text{Courses per inch}$

The wales and courses in the sample were as follows:

$\frac{72}{3.15} = 22.8$, wales.

$\frac{85}{3.62} = 23.4$, courses.

(268) Verification of the Analysis

If the results of the analysis satisfy the general knit-fabric formula they may be considered reliable. In this case there are three threads involved. The backing is treated as a proportion of the face fabric, for the backing is not formed into stitches as the other threads are. Consequently, only two threads have to be considered in the formula. If the stitches of each thread were alike, we could use the single equivalent thread; but, as the stitches are different, the complication involved in the reduction to a single equivalent thread may be avoided by the use of a test for each thread. That is the same as considering the two-thread fabric as two single-thread fabrics. The weights are added to obtain the total weight. The solution will make the principle obvious.

A convenient form of the general knit fabric formula for analysis is

(269) $\frac{\text{Wales X Courses}}{1.944 \text{ X Yarn number X Stitches}} = \text{Weight per square yard}$

Face $\frac{22.8 \times 23.4}{1.944 \times 29.1 \times 59.4} = .1585$

[illegible]

$$[illegible]$$

[illegible]

[illegible]

[illegible]

$$[illegible]$$

[illegible]

[illegible]

[illegible]

$$[illegible]$$

Binder $\frac{22.8 \times 23.4}{1.944 \times 29 \times 67} = .141$

Total calculated weight of face fabric .2995.

The backing was 47.6% of the whole fabric. 100 - 47.6 = 52.4, the percentage of face fabric. The calculated weight of the face fabric, .2995, divided by the proportion of the face fabric, .524, gives the calculated total weight, and this should be close to the actual weight determined from the sample.

The total calculated weight is .2995 ÷ .524 = .574.

The actual weight determined from the sample was .583.

The analysis may be considered sufficiently verified for practical purposes.

(270) Summary

Analysis of sample: blue napped double plush, dyed in piece; cotton face, cotton waste back.

Wales per inch	22.8
Courses per inch	23.4
Weight, lbs., per yard	.583

Proportions by weight of different yarns	Face	27.7	52.4
	Binder	24.7	
	Back	47.6	
		100.	

Cotton counts of yarn	Face	29.1	
	Binder	29.	
	Back	6.17	(8.43 grain, Cohoes standard)

Stitches per foot, Face 59.4; Binder 67.

(271) Warp

Warp knitting, especially in fine gages, presents some problems not generally met. The following analysis of a piece of silk warp glove fabric illustrates these problems. The analysis was to determine the number of the yarn. It was solved by means of the general knit fabric formula, since it is difficult to get sufficient free yarn to weigh, and since there is insufficient data for reliable determination of the number of fine yarn by means of its diameter.

(272) Determination of the Wales and Courses

Since this fabric is about as fine as any with which the analyst has to work,

a micrometer counter is preferable for counting the stitches. The gain therewith in time and accuracy would soon counterbalance the cost, if much work is to be done. However, it is possible to get reliable results with a pick glass - preferably of one inch aperture - and a fine pointer. A needle forced eye-first in the end of a pine stick makes a good pointer for this work.

The fabric should be laid flat on a blotter or other plane surface which will not allow it to slip; and it should be allowed to take its position in its natural shape - not stretched or twisted. The stitch counting should be done in several places in order to obtain a fair average. Each counting should follow a selected wale or course, as the case may be; and not less than three countings should be made in any one place.

The wales and courses in the sample were as follows:

	Wales.	Courses.
First position	56	66
	56	66
Second position	61	65
	60	65
	61	65
Third position	59	68
	59	67
	59	68
Total	471	530
Average	58.85	66.3

58.85 X 66.3 = 3900, the stitches per square inch.

(273) Weighing the Sample

The weighing of the sample is no different than that of any other sample. The weight in this case was as follows:

Weight, 84.75 grains.
Area, 129.10 square inches.

Weight in grains per square yard =

$$\underset{\text{(Weight of piece)}}{84.75} \times \underset{\text{(Inches in yard)}}{\frac{1296}{129.1}} = 851.$$

Weight in pounds per square yard =

$$\underset{\text{(Weight in grains)}}{851} \div \underset{\text{(Grains in pound)}}{7000} = .1215$$

(274) Determining the Stitches Per Foot of Yarn

The sample was knit with a side-to-side traverse of one needle space; so, in order to ravel it, lengthwise strips two wales in width had to be cut out of the piece. In order to have these strips of uniform length, a cutting piece should be trimmed out along courses, and the strips should be cut off the end. Sharp shears are necessary; the cutting should bisect the wales adjoining the two-wale strip; and the length of the strip should be sufficient to give a reasonable length of yarn, but not too long to cut out successfully. The suitable length may be determined by practice.

Each strip will ravel if it has been properly cut. If the cutting has run into the strip, the raveling will be in pieces - two, or more, according to the number of "run-ins." If the cutting has been too far away from the selected wales the raveling may snarl or be loaded up with lint. In any case, the lint from the severed stitches may cling to the raveled yarn; but that is not objectionable if the yarn has straightened out, since only the length of yarn is desired - not the weight, as would be the case in an ordinary determination of the yarn number. When a sufficient number of ravelings have been made to afford a reliable determination of the average length in relation to the stitches, the lengths should be measured. The method of measuring is described in the analysis of the double-plush sample.

The stitches per foot of the sample in question were as follows:

	(1) Length of yarn in inches	(2) Stitches	(3) (2) ÷ (1)
	7.5	120	16
	11.38	156	13.7
	11.	156	14.2
	11.1	156	14.
	10.75	153	14.2
	10.75	153	14.2
	11.	153	13.9
	10.87	153	14.1
Total	84.35	1200	

The formula for the stitches per foot when the lengths are expressed in inches is as follows:

(275) $$\text{Stitches per foot} = \frac{12 \times \text{Stitches in piece of yarn}}{\text{Length of yarn in inches}}$$

In this case it is not necessary to average the lengths and stitches before they are substituted in the formula; but we may use the totals, since the ratio is the same.

$$\text{Stitches per foot} = \frac{12 \times 1200}{84.35} = 171.$$

The third column in the tabulation is to test the correspondence of the different determinations. Evidently the correspondence increased as the work progressed; so a second stitch calculation was made with the last four determinations, as follows:

Length of yarn in inches.	Stitches.
10.75	153
10.75	153
11.	153
10.87	153
43.37	612

$$\text{Stitches per foot} = \frac{12 \times 612}{43.37} = 169.5$$

Since the first stitch determination was 171 and the second, and supposedly more reliable determination, was 169.5, it was decided to use 170.

(276) Determining the Yarn Number

The usefulness of the general knit-fabric formula is illustrated in this case, in which it is almost impossible - for a commercial analysis - to obtain sufficient yarn for a reliable weighing. Having the weight of the piece, the stitches per foot of yarn, and the wales and the courses, we are able to solve for the yarn number.

(277) Cotton yarn number =

$$\frac{\text{Wales} \times \text{Courses}}{1.944 \times \text{Stitches per foot} \times \text{Weight per square yard}}$$

The yarn number in the sample in question was as follows:

$$\text{Cotton yarn number} = \frac{58.85 \times 66.3}{1.944 \times 170 \times .1215} = 97.2$$

The silk numbers of the yarn are

	(Constant)		(Cotton number)		
Dram	305	÷	97.2	=	3.14
Denier	5280	÷	97.2	=	54.3

(278) Miscellaneous Problems

(279) Example. What can be done on a 600-needle (cylinder) rib machine with a yarn which by test coils 38 and 39 per half-inch?

The average number of coils per half inch is 38.5

$(38.5)^2 = 1482.25$

(280) Yarn number $= (\frac{1}{2}\text{ Coils})^2 \div 110.25 = 1482 \div 110.25 = 13.43.$

(281) Cut of machine $= \frac{1}{2}\text{ Coils} \div 4.2865 = 38.5 \div 4.29 = 9.$

(282) Stitches per foot $= \frac{1}{2}\text{ Coils} \div 1.0716 = 38.5 \div 1.07 = 36.$

(283) Wales per inch $= \frac{1}{2}\text{ Coils} \div 2. = 38.2 \div 2. = 19.25.$

(284) Courses per inch $= \frac{1}{2}\text{ Coils} \div 1.6 = 38.5 \div 1.6 = 24.1.$

(285) Pounds per square yard $= 18.987 \div 38.5 = .494.$

(286) Production, pounds per feed, 10 hours

$= 14443 \div (\frac{1}{2}\text{ Coils})^2 = 14443 \div 1482 = 9.74.$

(287) Production, square yards per feed, 10 hours

$= 760.1 \div \frac{1}{2}\text{ Coils} = 760 \div 38.5 = 19.75.$

(288) Tensile strength lengthwise (strip 1-inch wide)

$= 3000 \div \frac{1}{2}\text{ Coils} = 3000 \div 38.5 = 78.$

(289) Tensile strength crosswise (strip 1-inch wide)

$= 937.5 \div \frac{1}{2}\text{ Coils} = 937.5 \div 38.5 = 24.4.$

(290) Width from 600 needle cylinder

$= (600 \div \frac{1}{2}\text{ Coils}) \times 1.10 = \frac{600 \times 1.1}{38.5} = 17.1$

(Body rib machines generally make the fabric 10% wider than the theoretical width, hence the constant 1.10 in the width formula. (See section 100).

(291) Example. Solve the above problem by use of the yarn number. This facilitates comparison of the use of the two different units; namely, the coils per half-inch, and the yarn number.

(292) Yarn number

$= (\frac{1}{2}\text{ Coils})^2 \div 110.25 = 1482 \div 110.25 = 13.43$, say 13.

(293) Cut of machine $= 2.45 \sqrt{\text{No}} = 2.45 \times 3.6 = 8.8.$

(294) Stitches per foot $= 9.8 \sqrt{\text{No}} = 9.8 \times 3.6 = 35.$

(295) Wales per inch = $5.25 \times \sqrt{No} = 5.25 \times 3.6 = 18.9$.

(296) Courses per inch = $6.56 \sqrt{No} = 6.56 \times 3.6 = 23.6$.

(297) Pounds per square yard

$= 1.808 \div \sqrt{No.} = 1.808 \div 3.6 = .502$.

(298) Production, pounds per feed, 10 hours

$= 131 \div No = 131 \div 13 = 10$.

(299) Production, square yards per feed, 10 hours

$= 72.39 \div \sqrt{No} = 72.39 \div 3.6 = 20$.

(300) Tensile strength lengthwise (stripe 1-inch wide)

$= 286 \div \sqrt{No} = 286 \div 3.6 = 80$.

(301) Tensile strength crosswise (stripe 1-inch wide)

$= 89 \div \sqrt{No} = 89 \div 3.6 = 24.8$

(302) Width from 600 needle cylinder

= Half needles x width wale x 1.1.

$$= 300 \times 4 \times \frac{1}{21 \sqrt{No}} \times 1.1$$

$$= \frac{300 \times 4 \times 1.1}{21 \times 3.6} = 17.4$$

Since we used 13 yarn instead of 13.43 yarn, the results differ slightly from those calculated from the coils. Notice that the yarn number may be used advantageously when a serious of calculations are made with the same yarn number, because the square root needs to be extracted only once.

We have found what may be expected when this yarn coiling 38.5 turns to the half-inch is used on an ordinary latch-needle rib machine. Let us see what variations will result from its use on a spring-needle loop-wheel machine.

The change in the fabric-from rib to flat - will be one source of variation. Rib fabric is essentially two identical flat fabrics connected back to back. Consequently, the wales and courses will be the same; but the rib fabric will weight twice as much per square yard, and will have twice the longitudinal tensile strength, but will have only half the number of stitches per foot of yarn, because the back stitches are not counted.

The change in the type of machine introduces variations in the production,

because the speed and the relation of the yarn to the needle spacing is generally different in different machines. The loop-wheel machine runs at a higher needle speed than the latch-needle machine, and takes a heavier yarn for the same needle spacing, or for the same yarn takes a narrower needle spacing.

(303) Example. Suppose the yarn in the two preceding examples is used on a spring-needle loop-wheel machine. What of the above results will have to be modified. Solve by means of the coils per half-inch.

Cut is not generally used to designate the needle spacing of loop-wheel machines.

(304) Gage $= \frac{1}{2}$ Coils $\div 1.66 = 38.5 \div 1.66 = 23.$

Stitches per foot will be twice as many because all stitches are counted.

(305) Stitches per foot of yarn $= \frac{1}{2}$ Coils $\div .54 = 38.5 \div .54 = 71.$

The pounds per square yard will be only half as much, for in flat fabric there is only one stitch where there are two in rib fabric.

(306) Pounds per square yard $= 9.5 \div \frac{1}{2}$ Coils $= 9.5 \div 38.5 = .24.$

The production will be increased both because the needle speed is higher and because the needles are spaced more closely together.

(307) Production pounds per 10 hours per feed

$= 17{,}755 \div (\frac{1}{2}\text{ Coils})^2 = 17{,}555 \div 1482 = 12.$

(308) Production, square yards per 10 hours per feed

$= 1869 \div \frac{1}{2}$ Coils $= 1869 \div 38.5 = 48.5.$

The tensile strength lengthwise will be halved, because there will be half as many threads to stand the stress.

(309) Tensile strength lengthwise (strip 1-inch wide)

$= 1500 \div \frac{1}{2}$ Coils $= 1500 \div 38.5 = 39.$

(310) Example. Solve the above flat-fabric problems with the use of the yarn number, taking number 13, as before.

(311) Gage $= 6.32 \times \sqrt{\text{No}} = 6.32 \times 3.6 = 22.8$

(312) Stitches per foot of yarn $= 19.6$ No $= 19.6 \times 3.6 = 70.5.$

(313) Pounds per square yard $= .904 \div \sqrt{\text{No}} = .904 \div 3.6 = .25.$

(314) Production, pounds per 10 hours per feed

$= 161 \div \text{No} = 161 \div 13 = 12.4.$

(315) Production, square yards per 10 hours per feed

$= 178 \div \sqrt{No} = 178 \div 3.6 = 49.5.$

(316) Tensile strength lengthwise (strip 1-inch wide)

$= 142.86 \div \sqrt{No} = 143 \div 3.6 = 39.6.$

(317) Example. A ribber with 275 needles, the actual cut of which was 13.35, was required to knit nominal 50 two-ply yarn; but so much trouble was experienced in starting the machine, that calculations were called into question, with the following result.

The yarn was found to coil 50 turns per half-inch.

		Results	
		Calculated	Actual
(318) Width of fabric $=$ Needles $\div \frac{1}{2}$ Coils	$= 275 \div 50 =$	5.5	5.4
(319) Wales per inch $= \frac{1}{2}$ Coils $\div$ 2	$= 50 \div 2 =$	25.	25.5
(320) Courses per inch $= \frac{1}{2}$ Coils $\div$ 1.6	$= 50 \div 1.6 =$	31.2	28.
(321) Cut $= \frac{1}{2}$ Coils $\div$ 4.29	$= 50 \div 4.29 =$	11.65	13.35
(322) Stitches per foot $= \frac{1}{2}$ Coils $\div$ 1.07	$= 50 \div 1.07 =$	46.7	45.5

This example illustrates the use of knitting calculations. The machine in question was made to purchaser's specification. An experienced adjuster spent two days in getting it started, and then had to run it slowly in order to run it successfully. Naturally, some of the difficulty would be laid to the newness of the machine; but that did not seem to account for all of it. Was the remaining difficulty to be laid to the author of the specification or to the manufacturer? And, suppose the machine continued to give trouble; should the blame be put on the purchaser or the manufacturer? The solution of just such problems is one of the important uses of knitting calculations. Much of the misunderstanding in the industry would be dissipated by the adoption of rational bases for agreement.

The first important lesson to be learned is that the thickness of the yarn, and not its number, is the important criterion for its use on the machine. Of course, stiffness and compressibility also enter into the consideration. In accordance with the prevailing custom, this 50/2 yarn was evidently considered to be usable the same as its single equivalent, namely number 25. But really it is equivalent to a heavier yarn; for two fifties twisted together make a thicker thread than a single 25. The advisability of coiling the yarn in order to determine its thickness is also evident. This yarn coiled 50 turns to the half-inch, so it was as thick as a 23 yarn. Moreover, it was less compressible and more

wiry than single 23 hosiery yarn. The calculations show that the cut was too fine for average practice with even hosiery yarn.

The next question is whether the yarn is altogether too heavy for the cut. A good rule for the practical heavy limit of yarn for machines of this class is, Yarn $= (\text{Cut})^2 \div 8$. The cut used in this case was 13.35; so the heavy yarn limit is $13.35 \times 13.35 \div 8 = 22.3$. So technically the 50/2, even at its actual thickness, is within the limit; but when we consider the solidity and the stiffness of the ply yarn, it is evident that the requirements necessitate running the machine at about the limit of its capability.

The conclusion is that the specification was too exacting; and that the manufacturer could not properly be blamed if the machine failed to run properly.

(323) Example. A fabric is knit of two yarns, number 20 and number 30, both in the cotton count. The number 30 is 20% wool. What is the percentage of wool in the fabric?

First find the proportion of number 30 yarn in the fabric. That is the number of the other yarn divided by the sum of the numbers of the two yarns. $20 \div (20 + 30) = 20 \div 50 = .40$, the proportion of 30 yarn in the fabric. But 20% of this 30 yarn is wool so the proportion of wool in the fabric is $.20 \times .40 = .08$. The fabric is 8% wool.

(324) Example. A spinning mill contemplates knitting part of its product of number 20 yarn into ribbed goods. What will the fabric be like?

(325) $\frac{1}{2}$ Coils $= 10.5 \times \sqrt{\text{Yarn number}} = 10.5 \times \sqrt{20} = 10.5 \times 4.47 = 46.93$, say 47.

(326) Wales $= \frac{1}{2}$ Coils $\div 2 = 47 \div 2 = 23\frac{1}{2}$. Courses $= \frac{1}{2}$ Coils $\div 1.6 = 47 \div 1.6 = 29.4$. Weight in pounds per square yard $= 19 \div \frac{1}{2}$ Coils $= 19 \div 47 = .405$.

(327) Example. A sample of two-ply mercerized yarn coils 45 turns per half-inch. What is its cotton number considered as a single thread?

(328) Yarn number $= (\frac{1}{2} \text{ Coils})^2 \div 110.25$.
$45 \times 45 \div 110 = 2025 \div 110 = 18.4$.

(329) Example. The yarn in a gauze bandage - not ribbed - coils 57 turns per half-inch. It is knit 27 stitches to the foot of yarn. How much does the stitch vary from the normal?

(330) Yarn number $= (\frac{1}{2} \text{ Coils})^2 \div 110.25 = 57 \times 57 \div 110.25 = 3249 \div 110.25 = 29$.

(331) Stitches (for flat work) $= \frac{1}{2}$ Coils $\div .54 = 57 \div .54 = 105$.

Normal stitches $\div$ actual stitches $= 105 \div 27 = 3.9$. The loops are approximately 4-times as long as in regular fabric.

(332) Example. A mill is making rib goods that weigh $2\frac{1}{2}$ pounds to the dozen out of number 24 yarn. What will be the effect of a change to 30 yarn, with corresponding change of stitch?

Since this is a proportional change the solution may be effected with the coils or even the square roots of the yarn numbers. The coils per half-inch for 24 yarn are 51.44 and for 30 yarn, 57.51. These are very nearly in the ratio of 9 to 10, so we may use the latter figures and solve the problem mentally.

The weight per square yard is inversely as these numbers; that is, the fabric will be 10% lighter, practically a quarter of a pound per dozen.

The production in square yards - the production in which we are interested in this case - will be 10% less with the 30 yarn, provided the needle speed is maintained, and the cut is made 10% finer to correspond to the finer yarn.

The 30 yarn costs 30 cents as against 26 cents for the other yarn, but the quantities used are as 9 is to 10; so the relative cost for the finer yarn is as 270 is to 260, or approximately 4% more for the finer yarn on the basis of the same square-yardage.